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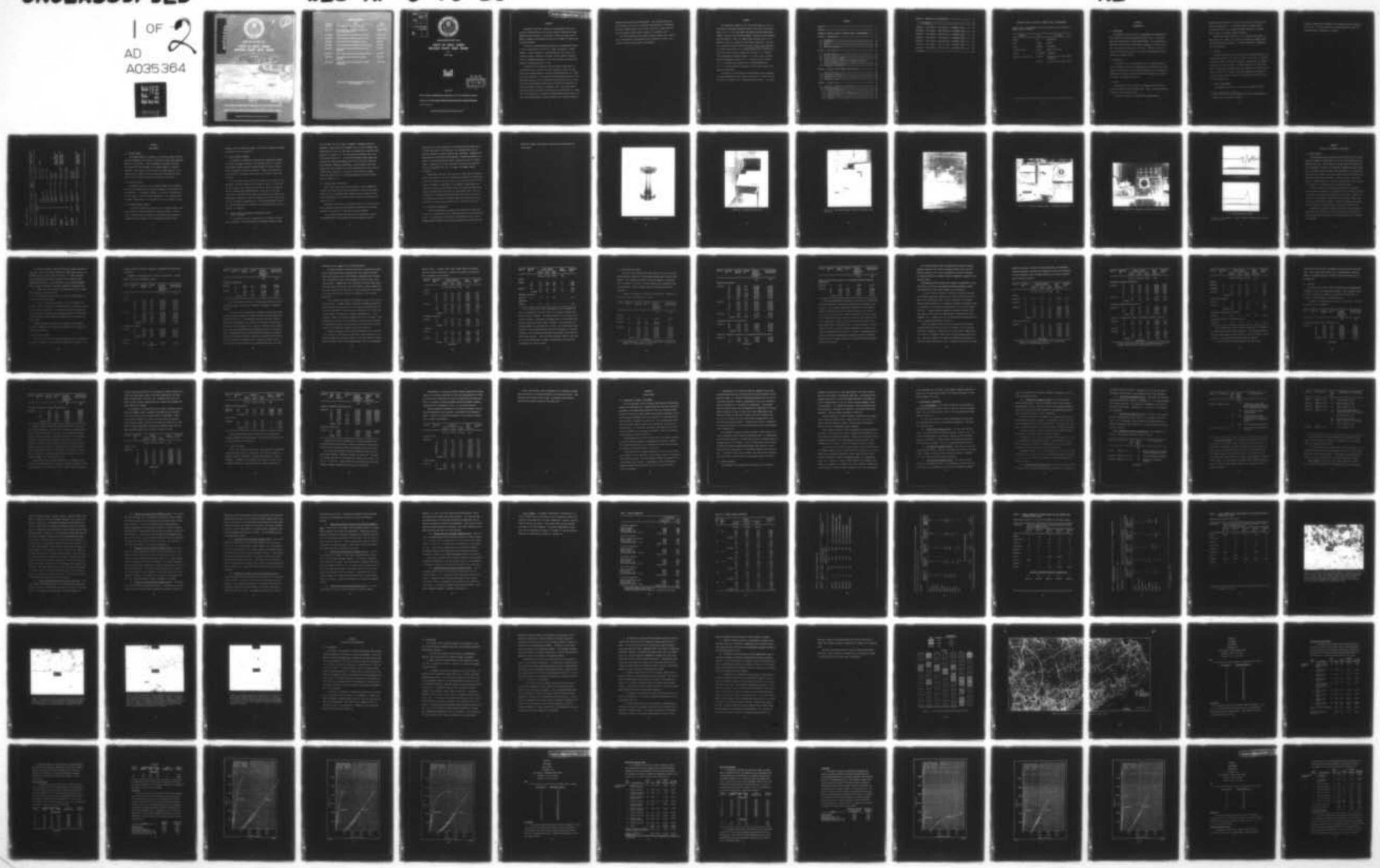

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MISCELLANEOUS PAPER C-70-16

TESTS OF ROCK CORES MACHIAS STUDY AREA, MAINE

by

R. W. Crisp

See 1473

August 1970

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Sponsored by Space and Missile Systems Organization, U. S. Air Force Systems Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

ASSOCIATED REPORTS

Report No.	Title	Date
MP C-69-3	Tests of Rock Cores, Warren Area, Wyoming	March 1969
MP C-69-12	Tests of Rock Cores, Mountain Home, Idaho, and Fairchild, Washington, Areas	September 1969
MP C-69-16	Tests of Rock Cores, Castle Study Area, California	October 1969
MP C-70-4	Tests of Rock Cores, Bergstrom Study Area, Texas	February 1970
MP C-70-6	Tests of Rock Cores, Scott Study Area, Missouri	May 1970
MP C-70-7	Tests of Rock Cores, Plattsburgh Study Area, New York	June 1970
MP C-70-9	Tests of Rock Cores, Duluth-Vermillion Study Area, Minnesota	June 1970
MP C-70-10	Tests of Rock Cores, Michigamme Study Area, Michigan	June 1970
MP C-70-11	Tests of Rock Cores, Pease Study Area, New Hampshire	July 1970
MP C-70-14	Tests of Rock Cores, Pembine Study Area, Michigan and Wisconsin	August 1970

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ARMY-MRC VICKSBURG, MISS.

ABSTRACT

Laboratory tests were conducted on representative rock core specimens received from six core holes located in Hancock and Washington Counties in Maine. The results of these tests were used to gage the quality and uniformity of the rock to depths of 200 feet below ground surface.

The core was petrographically identified as predominantly granite with lesser amounts of rhyolite, basalt, and gabbro. Schmidt hardness, specific gravities, compressional wave velocities, and ultimate uniaxial compressive strengths varied somewhat throughout the area, depending primarily on rock type, texture, and nature and degree of fracturing present, if any.

Evaluation of the materials from the Machias study area on a hole-to-hole basis indicates that the porphyritic granite is quite uniform and rather competent, offering good possibilities as a competent hard rock medium. The uniformly medium-grained granite was somewhat more variable, with one specimen from Hole MA-CR-13 (at a depth of 39 feet) and several specimens from Hole MA-CR-20 yielding physical test results typical of incompetent rock. The intact medium-grained granite should offer relatively good possibilities as a competent hard rock medium; the highly fractured medium-grained granite and that containing weathered fracture surfaces were, however, generally

incompetent and therefore unsatisfactory. The rhyolite and the basalt and gabbro must also be considered unsatisfactory, as specimens removed at depths greater than 100 feet from each of these holes exhibited physical characteristics typical of incompetent rock.

The above evaluations were based on rather limited data. Therefore, more extensive investigation will be required in order to accurately assess the areas under consideration.

PREFACE

This study was conducted in the Concrete Division of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Air Force Space and Missile Systems Organization (SAMSO) of the Air Force Systems Command. The study was coordinated with CPT Rupert G. Tart, Jr., SAMSO Project Officer, and Mr. M. V. Anthony of TRW, Inc., Norton Air Force Base, California. The work was accomplished during the period November 1969 to July 1970 under the general supervision of Mr. Bryant Mather, Chief, Concrete Division, and under the direct supervision of Messrs. J. M. Polatty, Chief, Engineering Mechanics Branch, W. O. Tynes, Chief, Concrete and Rock Properties Section, and K. L. Saucier, Project Officer. Mr. C. R. Hallford was responsible for the petrography work. Mr. R. W. Crisp performed the majority of the program analysis and prepared this report.

Directors of the WES during the investigation and the preparation and publication of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows.

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
feet per second	0.3048	meters per second
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms (force) per square centimeter
	6.894757	kilonewtons per square meter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The purpose of this study was to supplement the information being obtained for the area evaluation study by the U. S. Air Force Space and Missile Systems Organization (SAMSO). It was necessary to determine the properties of the specific materials in order to analyze the quality and uniformity of the rock. Results of tests on cores from the Machias study area of Hancock and Washington Counties in Maine are reported herein.

1.2 OBJECTIVE

The objective of this investigation was to conduct laboratory tests on samples from areas containing hard, near-surface rock to determine the integrity and the mechanical behavior of the materials as completely as possible, analyze the data thus obtained, and report the results to appropriate parties.

1.3 SCOPE

Laboratory tests were conducted on samples received from the field as indicated on the following page. Table 1.1 gives pertinent information on the various tests.

Tests were conducted to determine the general quality,

uniformity, and integrity of the rock from the area. Physical properties determined were: (1) relative hardness (Schmidt number), (2) specific gravity, (3) ultimate uniaxial compressive strength, and (4) static and dynamic elastic properties.

Special tests were conducted to: (1) determine the degree of anisotropy of the sampled rock, and (2) determine and compare direct and indirect tensile strengths. A limited petrographic examination was also performed.

1.4 SAMPLES

Samples were received from seven holes in the Machias study area designated as MA-CR-4, -12, -13, -14, -18, -20, and -29. All samples were NX-size cores (2-1/8-inch[1] diameter). Specimens of the required dimensions, as given in Table 1.1, were prepared for the individual tests. Quality and uniformity tests were conducted on selected specimens from all holes. Special tests were conducted on specimens selected from the various core holes to represent differences in rock type, weathering, etc.

1.5 REPORT REQUIREMENTS

The immediate need for the test results required that data

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[1] A table of factors for converting British units of measurement to metric units is presented on page 8.

reports be compiled and forwarded to the users as work was completed on each hole. The data reports of the individual test results are included herein as Appendixes A through G.

TABLE 1.1 SUMMARY OF TESTS

Test	Specimen Size	Test Equipment	Recording Equipment	Measured Properties	Computed Properties
Relative hardness	1 diameter by 2 diameters	Schmidt hammer	--	Relative hardness	--
Specific gravity		Scales	--	Specific gravity	Density
Indirect tension		440,000-pound test machine	--	Tensile strength	--
Direct tension		30,000-pound test machine	--	Tensile strength	--
Unconfined compression		440,000-pound test machine	X-Y recorder	Compressive strength	--
Cyclic compression		440,000-pound test machine	X-Y recorder	Compressive strength	Young's, shear, and bulk moduli and Poisson's ratio
Ultrasonic velocity		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio
Dynamic elastic moduli		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	--
Petrographic examination	Variable	Microscopes, X-ray diffraction	--	Appearance, texture, and mineralogy	--
Anisotropy	1 diameter by 1 diameter	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio

CHAPTER 2

TEST METHODS

2.1 SCHMIDT NUMBER

The Schmidt number is a measure of the relative degree of hardness as determined by the degree of rebound of a small mass propelled against a test surface. Twelve readings per specimen were taken. The average of these readings is the Schmidt number, or relative hardness. The hardness is often taken as an approximation of rock quality and can frequently be correlated with other physical properties such as strength, density, and modulus of elasticity.

2.2 SPECIFIC GRAVITY

The specific gravity of the as-received samples was determined by the loss-of-weight method conducted according to Method CRD-C 107 of Reference 1. A pycnometer (Figure 2.1) is used to determine the loss of weight of the sample upon submergence. The specific gravity is equal to the weight in air divided by the loss of weight in water.

2.3 INDIRECT TENSILE STRENGTH

The tensile strength was determined by the indirect method, commonly called the tensile splitting or Brazilian method, in which a tensile failure stress is induced in a cylindrical test specimen by a compressive force applied on two diametrically opposite line

elements of the cylindrical surface. The test was conducted according to Method CRD-C 77 of Reference 1.

2.4 DIRECT TENSILE STRENGTH

For purposes of comparison, specimens were prepared and tested for tensile strength according to the American Society for Testing and Materials (ASTM) proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." Tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens.

For the direct tension tests, the specimens were right circular cylinders, the sides of which were straight to within 0.01 inch over the full length of the specimen and the ends of which were parallel and not departing from perpendicularity to the axis by more than 0.25 degree. Cylindrical metal caps were cemented to the ends of the specimens and provided the means for applying the direct tensile load. The load was applied continuously by a 30,000-pound-capacity universal testing machine and at a constant rate such that failure occurred within 5 to 15 minutes.

2.5 ULTIMATE UNIAXIAL COMPRESSIVE STRENGTH AND STATIC ELASTIC CONSTANTS

The unconfined and cyclic compression test specimens were prepared according to the ASTM and Corps of Engineers standard method

of test (CRD-C 147) for triaxial strength of undrained rock core specimens. Essentially, the specimens were cut with a diamond blade saw (Figures 2.2 and 2.3), and prior to testing the cut surfaces were ground to a tolerance of 0.001 inch across any diameter with a surface grinder (Figure 2.4). Electrical-resistance strain gages were utilized for strain measurements, two each in the axial (vertical) and horizontal (diametral) directions. Static Young's, bulk, and shear moduli were computed from strain measurements and were based on tangent moduli computed at 50 percent of the ultimate strength. Stress was applied with a 440,000-pound-capacity universal testing machine (Figure 2.5).

2.6 DYNAMIC ELASTIC PROPERTIES

Bulk, shear, and Young's moduli, Poisson's ratio, compressive velocity, and shear velocity were determined on selected rock specimens by use of the proposed ASTM "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock."

Specimens were prepared by cutting the ends of the NX-size cores with a diamond blade saw and grinding these surfaces with a surface grinder to a tolerance of 0.001 inch across any diameter.

The test method essentially consisted of generating a wave in the specimen with a pulse generator unit and measuring, with an

oscilloscope, the time required for the compression and shear waves to travel the length of the specimen, the resulting wave velocity being the distance traveled divided by the traveltime. Equipment for measuring pulse velocities and photographs of typical waveforms as recorded on the oscilloscope are shown in Figures 2.6 and 2.7, respectively. Compressive and shear velocities, along with the bulk density of the specimen, were used to compute the dynamic elastic properties.

Compressional and shear wave velocities; bulk, shear, and Young's moduli; and Poisson's ratio were determined according to the ASTM proposed method, except that in the case of the special tests used to determine the degree of anisotropy of the samples, compressional and shear wave velocities were measured along two mutually perpendicular, diametral (lateral) axes and along the longitudinal axis. This was facilitated by grinding four 1/2-inch-wide strips down the sides of the cylindrical surface at 90-degree angles and generating the compressional and shear waves perpendicular to these ground surfaces.

2.7 PETROGRAPHIC EXAMINATION

A limited petrographic examination was conducted on samples selected to be representative of the material received from the several holes. The examination was limited to identifying the rock, determining general condition, identifying mineralogical constituents, and

noting any unusual characteristics that may have influenced the test results.

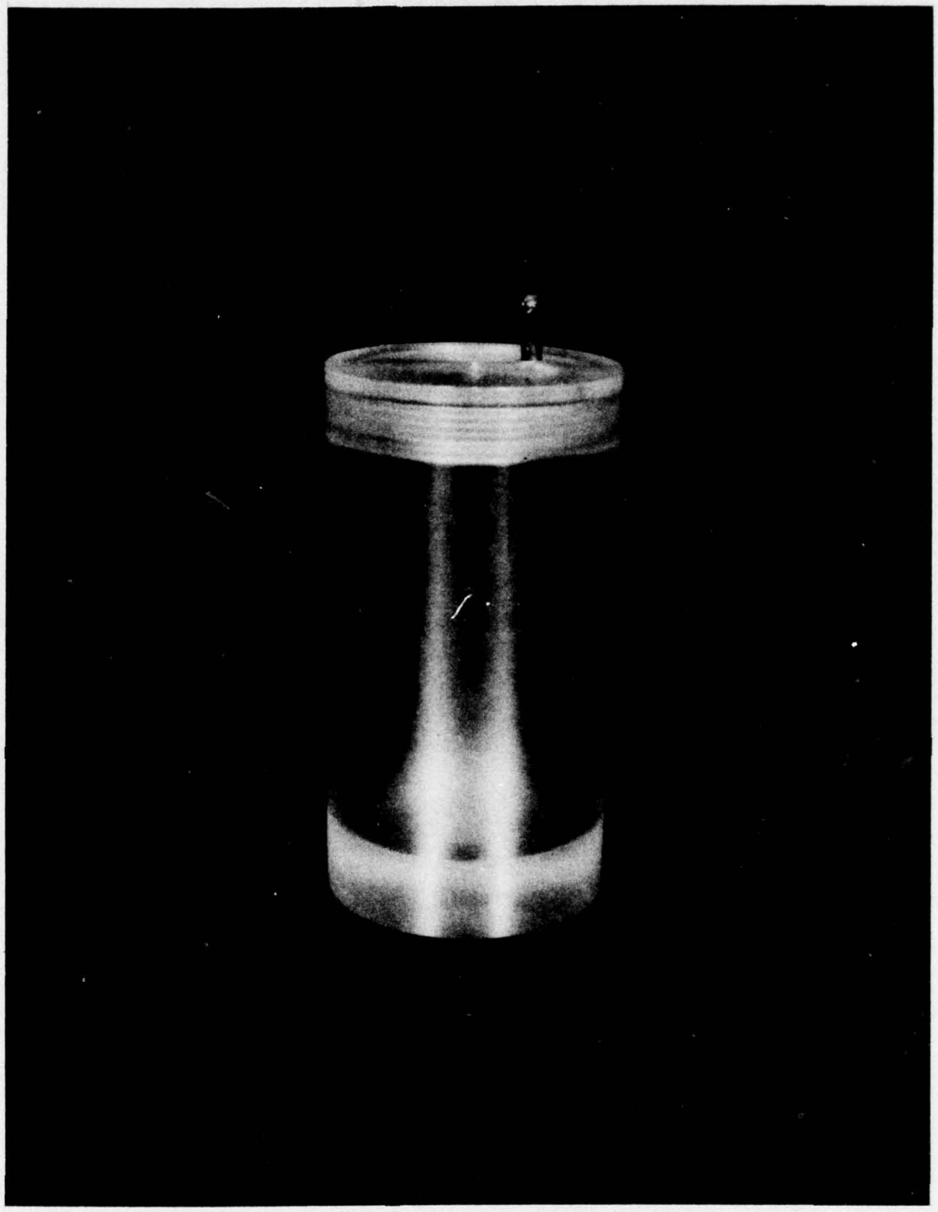


Figure 2.1 Pycnometer chamber.

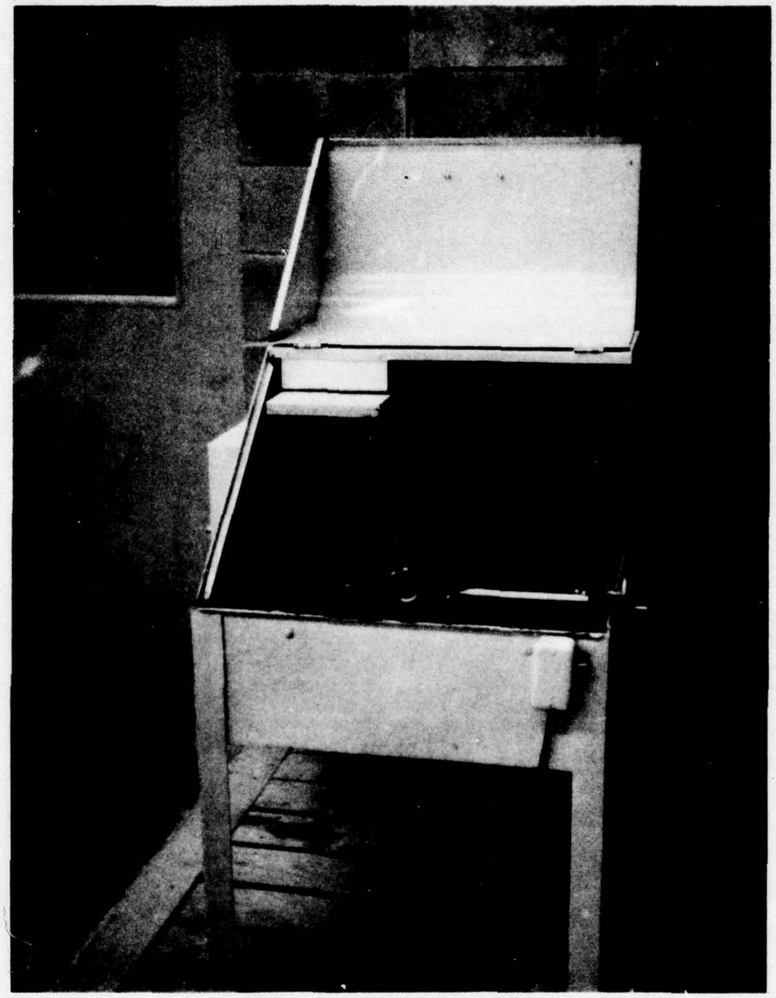


Figure 2.2 Diamond blade slab saw.

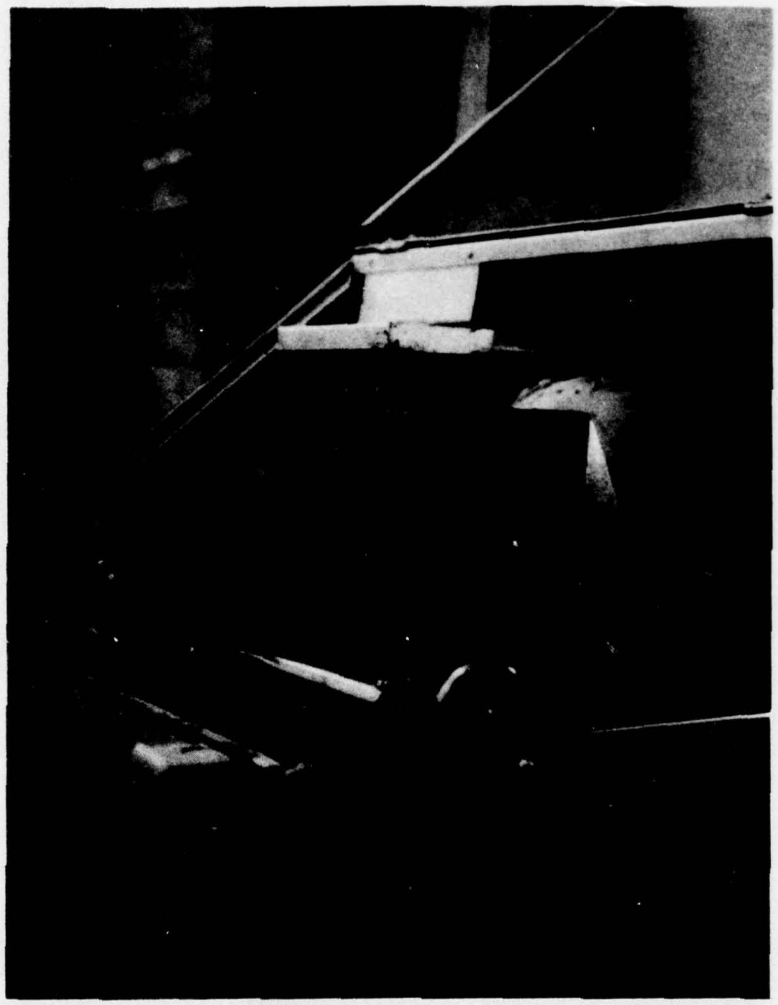


Figure 2.3 Vise-type specimen carriage for diamond blade slab saw.

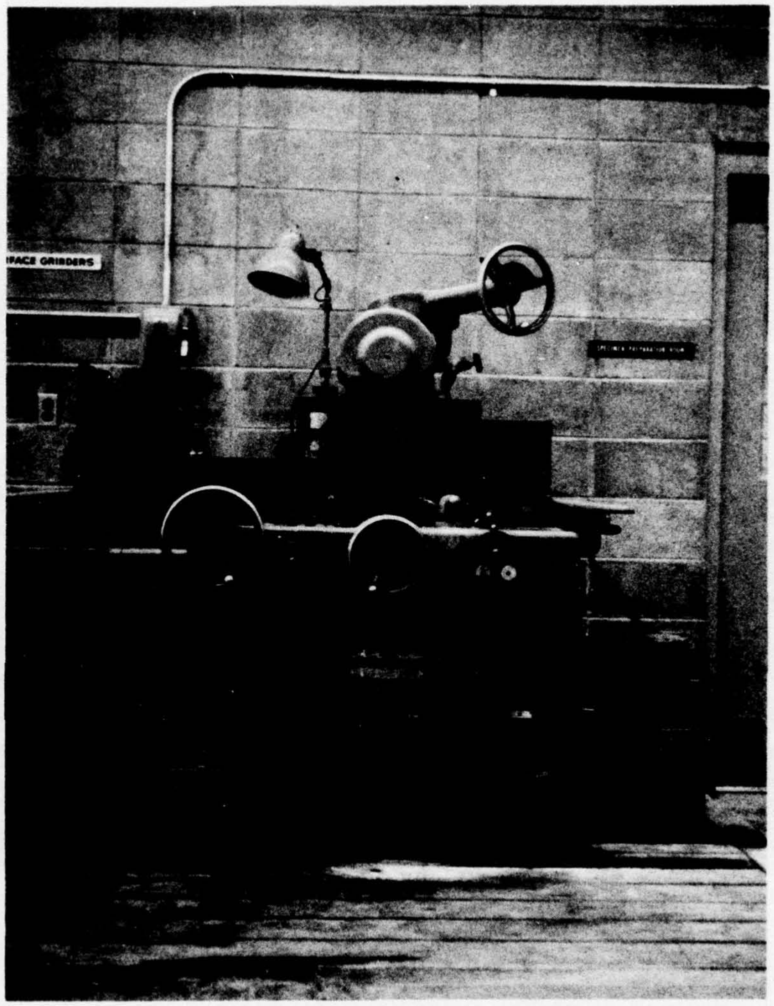


Figure 2.4 Hydraulic surface grinder.

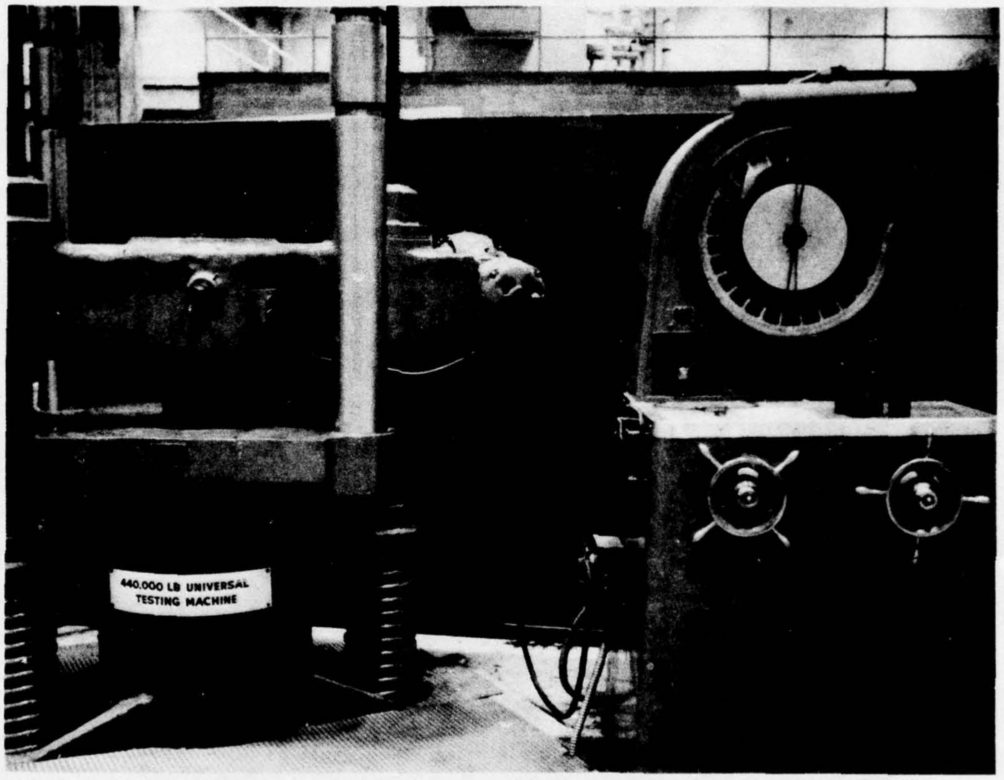


Figure 2.5 Universal testing machine (440,000-pound capacity).

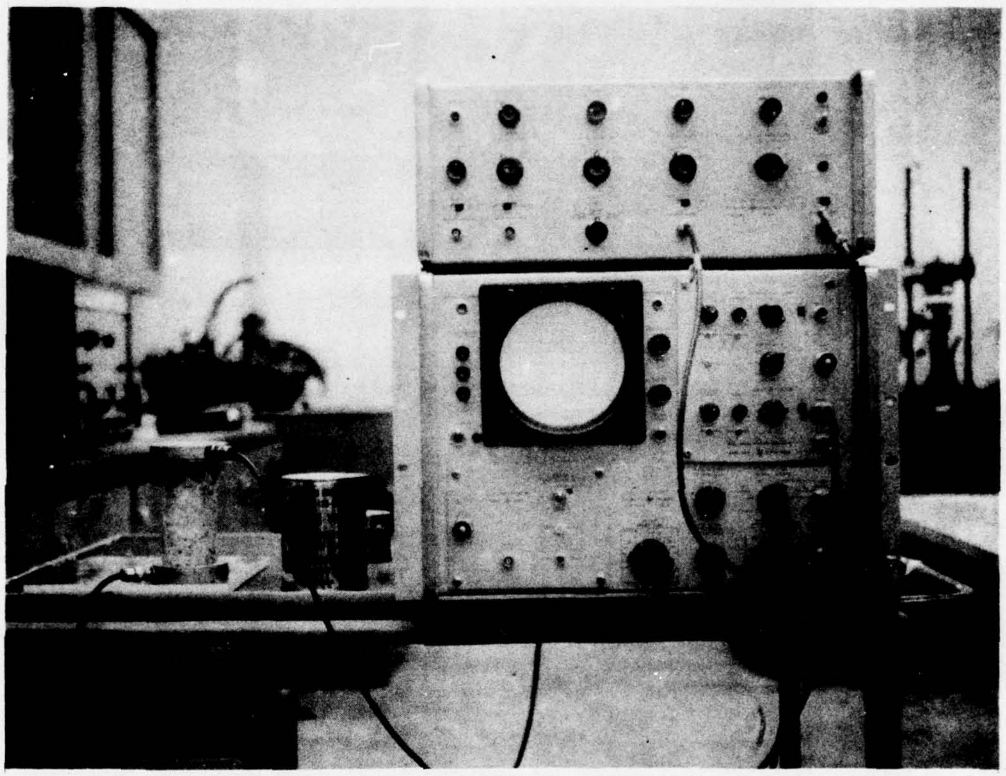
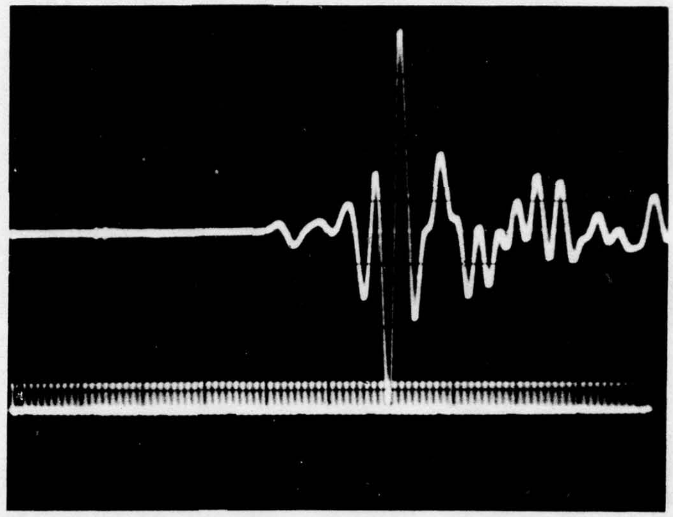
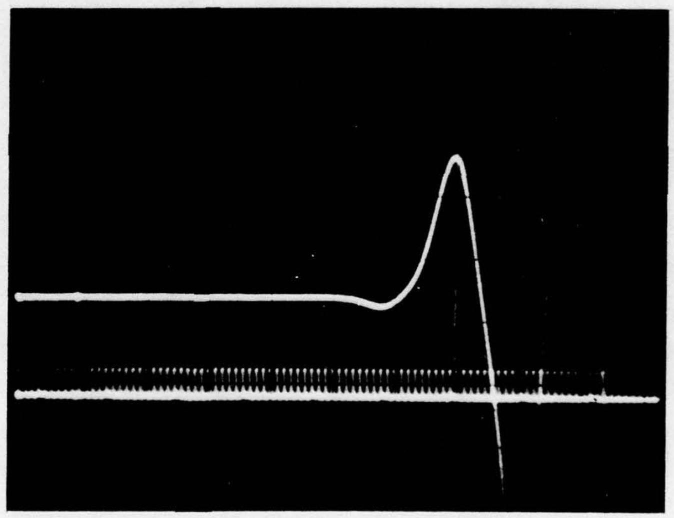


Figure 2.6 Equipment for measuring ultrasonic pulse velocities.



a. Shear wave pulse.



b. Compressional wave pulse.

Figure 2.7 Photographs of typical ultrasonic waveforms as displayed on oscilloscope.

CHAPTER 3

QUALITY AND UNIFORMITY TEST RESULTS

3.1 TESTS UTILIZED

The following physical properties were selected for use in evaluating the quality and uniformity of the rock core received from the Machias study area: Schmidt number, specific gravity, ultimate uniaxial compressive strength, and ultrasonic compressional pulse velocity. Ultrasonic elastic constants were determined for all specimens tested and were compared with static elastic constants determined for selected representative specimens. Static elastic constants were based on a tangent modulus of elasticity and Poisson's ratio computed at 50 percent of ultimate uniaxial compressive strength.

The core received from the Machias study area was generally rather uniform in composition and comprised four principal rock types: (1) granite, (2) rhyolite, (3) gabbro, and (4) basalt. Granite was by far the most abundant, comprising the entire core received from five of the seven holes evaluated. Relatively insignificant quantities of tonalite and pegmatite were also received from the area.

Differences in ultimate uniaxial compressive strength appear to have arisen from variation in rock type coupled with variation in nature, number, and inclination of fractures present in the individual specimens.

To facilitate analysis, data were generally grouped according to rock type. Due to the extreme variation in grain size, however, the granites were also divided into two groups: (1) black and white, very coarse-grained porphyritic granite; and (2) pink and gray, medium-grained granite. Where applicable, these general groupings were subdivided according to physical conditions as defined below:

1. Intact rock core, which was macroscopically free of joints, seams, vesicles, and/or fractures.

2. Moderately fractured rock core containing horizontally or vertically oriented fractures.

3. Highly to critically fractured rock core containing well developed systems of fracture, weathered systems of fracture, or critically oriented fractures, i.e., fractures inclined with respect to the horizontal at such angles that shearing stresses of failure magnitude developed when the specimen was subjected to relatively low axial stress.

Detailed physical test results are presented in Appendixes A through G; summaries of the results are tabulated in the various sections of this chapter.

3.2 PORPHYRITIC GRANITE

The entire cores received from Holes MA-CR-4 and -14 were petrographically identified as black and white porphyritic granite. Many

specimens contained fractures ranging in orientation from horizontal to vertical.

A summary of the physical test results is given below. Detailed results are given in Appendixes A and D.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Intact:					
MA-CR-4	3	2.61	50.4	28,760	15,220
	13	2.64	52.8	22,030	15,230
	16	2.64	51.4	20,330	10,550
	19	2.65	57.2	27,420	14,540
	21	2.65	55.8	20,970	16,150
	23	2.67	53.2	22,730	13,810
MA-CR-14	2	2.67	54.3	20,300	10,970
	7	2.67	48.7	21,300	11,390
	17	2.67	--	22,850	11,990
	19	2.67	56.8	20,210	11,980
	21	2.68	56.7	22,880	11,750
	Average	2.66	53.7	22,710	13,050
Moderately Fractured:					
MA-CR-14	5	2.66	52.8	18,850	12,400
	13	2.65	55.3	19,700	11,540
	15	2.65	51.5	20,700	12,320
	Average	2.65	53.2	19,750	12,090
Weathered:					
MA-CR-4	4	2.64	49.6	13,330	12,190

(Continued)

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Weathered (Continued):					
MA-CR-4	7	2.60	--	10,760	10,870
	11	2.63	50.7	12,760	10,670
MA-CR-14	9	2.64	43.0	11,060	7,480
	10	2.66	--	16,820	9,910
	Average	2.63	47.8	12,950	10,220

All of the porphyritic granite tested exhibited physical characteristics typical of those of a material of marginal to competent quality.

The intact core was consistently competent, yielding an average ultimate uniaxial compressive strength of 22,710 psi and ranging from 20,210 to 28,760 psi. Compressional wave velocities were, however, rather low, particularly for a material with ultimate strength properties such as were typical here. These low velocities were probably due to the very coarse-grained and porphyritic texture of this material. Interestingly, while ultimate uniaxial compressive strengths yielded by the intact porphyritic granites from Holes MA-CR-4 and -14 were very similar, compressional wave velocities yielded by the intact material from Hole MA-CR-14 were significantly lower than those

exhibited by the comparable core from Hole MA-CR-4.

The three moderately fractured specimens of porphyritic granite tested exhibited physical characteristics only slightly different from those yielded by the intact material, indicating that the presence of a moderate degree of fracturing had little, if any, effect upon strength. Compressional wave velocities yielded by these specimens (all from Hole MA-CR-14) were very similar to those exhibited by the intact core from the same hole, a further indication of the apparently negligible effects of moderate fracturing on such physical properties.

Several weathered specimens of porphyritic granite were tested from each hole. Ultimate uniaxial compressive strengths exhibited by these specimens were significantly lower than those exhibited by the moderately fractured or intact core, an indication of the rather pronounced effect of weathering on strength characteristics. In no instance, however, did ultimate strength fall below 10,000 psi. Compressional wave velocities also showed the rather pronounced effects of weathering, generally falling 2,000 to 3,000 fps below the values typical of the moderately fractured and intact materials.

Static and dynamic elastic constants determined for the porphyritic granite from this area, as indicated in the tabulation on the following page, were relatively uniform, with static values of Young's modulus generally found to be slightly higher than the corresponding

dynamic values. A general trend toward higher moduli with greater ultimate uniaxial compressive strength was noticeable, particularly with the dynamic elastic moduli.

Hole No.	Specimen No.	Dynamic Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Intact:						
MA-CR-4	3	6.3	4.9	2.5	8,360	0.28
	13	5.9	5.2	2.3	7,970	0.31
	16	3.2	2.2	1.3	5,990	0.26
	19	5.9	4.5	2.3	8,040	0.28
	21	6.3	6.1	2.4	8,160	0.33
	23	6.0	3.6	2.5	8,270	0.22
MA-CR-14	2	3.8	2.2	1.6	6,640	0.21
	7	4.2	2.4	1.7	6,950	0.20
	17	4.7	2.6	2.0	7,370	0.20
	19	4.9	2.3	2.1	7,660	0.15
	21	4.8	2.2	2.1	7,600	0.14
	Average	5.1	3.5	2.1	7,550	0.23
Moderately Fractured:						
MA-CR-14	5	4.9	2.8	2.0	7,500	0.21
	13	4.2	2.4	1.8	7,020	0.21
	15	5.0	2.6	2.1	7,680	0.18
	Average	4.7	2.6	2.0	7,400	0.20
Weathered:						
MA-CR-4	4	4.8	2.6	2.0	7,520	0.19
	7	3.5	2.3	1.4	6,300	0.25
	11	3.7	1.9	1.6	6,680	0.18
MA-CR-14	9	2.0	0.7	1.0	5,170	0.04
	10	3.2	1.8	1.3	6,080	0.20
	Average	3.4	1.9	1.5	6,350	0.17

(Continued)

Hole No.	Specimen No.	Static Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Intact:						
MA-CR-4	3	7.1	3.3	3.1	--	0.13
	13	7.5	3.9	3.2	--	0.18
	23	7.5	3.6	3.3	--	0.15
MA-CR-14	21	7.8	3.1	3.6	--	0.09
	Average	7.5	3.5	3.3	--	0.14
Moderately Fractured:						
MA-CR-14	13	7.6	6.5	2.9	--	0.31
Weathered:						
MA-CR-14	9	3.4	1.8	1.4	--	0.19

Static stress-strain curves (Appendixes A and D) revealed the intact and moderately fractured cores to be somewhat inelastic and rather brittle at failure. The upward concavity of the initial portions of several of the curves was probably due to crack and/or void closure during the initial stages of loading. Some hysteresis and residual strain were exhibited upon cycling. The stress-strain curve yielded by the weathered specimen revealed this material to be quite inelastic, with considerable hysteresis and residual strain being exhibited upon cycling. Unlike the other specimens tested in this manner, the weathered granite yielded a stress-strain curve that was curvilinear over the full range.

3.3 NONPORPHYRITIC GRANITE

The entire cores received from Holes MA-CR-12, -13, and -20 were petrographically identified as uniformly medium-grained, pink and gray granite. Most specimens contained fractures ranging in orientation from horizontal to vertical. Several specimens were weathered along these fractures. Three specimens tested contained quartz-filled fractures.

A summary of physical test results is given below. Detailed results are given in Appendixes B, C, and F.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Intact:					
MA-CR-12	21	2.61	--	19,700	17,570
MA-CR-13	1	2.64	49.7	30,550	a
	3	2.65	54.0	24,580	a
MA-CR-20	3	2.63	53.2	30,680	17,620
	5	2.64	56.9	27,880	17,800
	7	2.62	--	25,620	18,410
	9	2.59	55.2	19,760	18,160
	11	2.51	57.2	29,880	19,480
	Average	2.61	54.4	26,080	18,170

(Continued)

[a] Compressional wave velocities were omitted due to questionable accuracy in the measurement process.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Moderately Fractured:					
MA-CR-12	5	2.65	57.0	37,050	18,770
	8	2.60	--	18,180	18,730
	10	2.60	51.8	17,480	17,610
	11	2.62	--	26,520	18,770
	15	2.62	57.2	29,090	17,840
	17	2.60	57.9	20,730	17,390
	18	2.62	57.8	43,030	17,970
	20	2.61	56.3	39,330	18,740
MA-CR-13	6	2.65	57.3	23,710	16,900
	7	2.65	57.4	24,700	18,170
	8	2.64	53.7	16,240	16,030
	9	2.62	50.6	14,910	14,820
	11	2.64	--	16,110	15,820
	13	2.63	58.8	18,420	17,940
MA-CR-20	13	2.61	--	17,060	18,050
	Average	2.62	56.0	24,170	17,570
Containing Quartz-Filled Fractures:					
MA-CR-20	17	2.63	50.0	19,240	17,780
	18	2.62	45.5	11,030	18,070
	19	2.62	55.7	21,850	19,100
	Average	2.62	50.4	17,370	18,320
Highly or Critically Fractured or Containing Weathered Fractures:					
MA-CR-12	3	2.62	58.4	8,060	16,990
	6	2.60	57.4	9,470	18,540
	13	2.62	58.2	10,390	17,620

(Continued)

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Highly or Critically Fractured or Containing Weathered Fractures (Continued):					
MA-CR-13	5	2.56	--	1,970	14,270
MA-CR-20	15	2.58	50.9	5,760	17,240
	16	2.50	41.2	6,300	14,260
	21	2.58	52.5	2,120	17,340
	Average	2.58	53.1	6,300	16,610

Physical characteristics exhibited by the intact and moderately fractured specimens of medium-grained granite were generally quite similar in most respects, apparently indicating that the moderate degree of fracturing had little effect on physical test results. There was a noticeably larger degree of scatter in the data yielded by the moderately fractured core, but this could well have been due to the considerably greater number of specimens representing this group rather than to fracturing alone. Ultimate uniaxial compressive strength for the two groups averaged approximately 25,000 psi and ranged from approximately 15,000 to 43,000 psi. Compressional wave velocities averaged approximately 18,000 fps, which is noticeably greater than the average velocity of the intact porphyritic granite previously discussed.

The three specimens tested containing quartz-filled fractures exhibited physical test results averaging slightly lower than the averages yielded by the intact and moderately fractured specimens. One specimen yielded an ultimate uniaxial compressive strength in the marginal range.

Compressional wave velocities were similar in magnitude to those exhibited by the intact and moderately fractured specimens, apparently unaffected by the quartz filling in the fractures.

The highly fractured specimens, critically fractured specimens, and specimens containing fractures along which weathering had taken place were significantly weaker than the remainder of the medium-grained granite specimens, the reduction in degree of competency being due apparently to the nature and orientation of the physical discontinuities. Ultimate uniaxial compressive strengths averaged 6,300 psi, which is well within the range defined as characteristic of incompetent rock. Compressional wave velocities were also substantially lower, averaging approximately 16,600 fps.

Static and dynamic elastic constants exhibited by the medium-grained granite from this area were, as indicated in the following tabulations, moderate in magnitude, with static Young's moduli generally found to be slightly greater than the corresponding dynamic values. Constants yielded by the intact and moderately fractured specimens were rather consistent in value. Constants yielded by the highly

fractured specimens, critically fractured specimens, and specimens containing weathered fractures were somewhat scattered and frequently of lesser magnitudes than constants yielded by the intact and moderately fractured specimens.

Hole No.	Specimen No.	Dynamic Modulus			Shear Wave Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Intact:						
MA-CR-12	21	8.1	6.7	3.1	9,430	0.30
MA-CR-13	1	a	a	a	a	a
	3	a	a	a	a	a
MA-CR-20	3	8.0	6.9	3.1	9,300	0.31
	5	8.2	7.1	3.1	9,390	0.31
	7	9.0	7.4	3.4	9,890	0.30
	9	8.6	7.1	3.3	9,770	0.30
	11	9.1	8.2	3.4	10,110	0.32
	Average	8.5	7.2	3.2	9,650	0.31
Moderately Fractured:						
MA-CR-12	5	8.8	8.2	3.3	9,630	0.32
	8	8.3	8.2	3.1	9,410	0.33
	10	7.8	6.9	3.0	9,190	0.31
	11	8.8	8.0	3.4	9,750	0.32
	15	7.5	7.5	2.8	8,920	0.33
	17	7.6	6.8	2.9	9,080	0.31
	18	8.6	7.0	3.3	9,670	0.30
	20	5.3	9.8	1.9	7,340	0.41

(Continued)

[a] Shear wave velocities were omitted due to questionable accuracy in the measurement process.

Hole No.	Specimen No.	Dynamic Modulus Young's	Dynamic Modulus Bulk	Dynamic Modulus Shear	Shear Wave Velocity	Poisson's Ratio
		10^6 psi	10^6 psi	10^6 psi	fps	
Moderately Fractured (Continued):						
MA-CR-13	6	7.7	6.2	3.0	9,150	0.29
	7	7.9	7.9	3.0	9,090	0.33
	8	7.2	5.4	2.8	8,930	0.27
	9	6.4	4.3	2.6	8,550	0.25
	11	6.9	5.3	2.7	8,720	0.28
	13	7.7	7.5	2.9	9,060	0.33
MA-CR-20	13	6.1	8.5	2.2	7,940	0.38
	Average	7.5	7.2	2.9	8,960	0.32
Containing Quartz-Filled Fractures:						
MA-CR-20	17	9.6	6.0	3.9	10,490	0.23
	18	8.5	7.1	3.3	9,640	0.30
	19	10.3	7.4	4.1	10,760	0.27
	Average	9.5	6.8	3.8	10,300	0.27
Highly or Critically Fractured or Containing Weathered Fractures:						
MA-CR-12	3	7.3	6.4	2.8	8,900	0.31
	6	8.6	7.7	3.3	9,660	0.31
	13	8.0	6.9	3.0	9,280	0.31
MA-CR-13	5	7.0	2.2	3.6	10,210	b
MA-CR-20	15	6.1	7.3	2.2	8,040	0.36
	16	5.3	4.1	2.1	7,850	0.28
	21	8.1	6.2	3.2	9,530	0.28
	Average	7.2	9.7	2.9	9,080	0.31

(Continued)

[b] Poisson's ratio not computed due to unrealistically high ratio of shear wave velocity to compressional wave velocity.

Hole No.	Specimen No.	Static Modulus			Shear Wave Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Intact:						
MA-CR-12	21	9.3	4.5	4.0	--	0.16
MA-CR-13	1	8.7	3.7	3.9	--	0.11
MA-CR-20	3	9.3	5.4	3.8	--	0.21
	Average	9.1	4.5	3.9		0.16
Moderately Fractured:						
MA-CR-12	8	9.3	4.8	3.9	--	0.18
MA-CR-13	13	7.8	3.7	3.4	--	0.14
	Average	8.6	4.2	3.6		0.16
Containing Quartz-Filled Fractures:						
MA-CR-20	17	10.9	4.0	5.2	--	0.05
Containing Critically Oriented Fractures:						
MA-CR-12	6	3.0	1.2	1.4	--	0.09

Static stress-strain curves yielded by specimens of material of this type were usually somewhat inelastic. All specimens subjected to load cycling exhibited some hysteresis; in most instances, strain appeared to be completely recoverable upon load removal.

The one critically fractured specimen for which static

stress-strain relations were determined yielded an entirely nonlinear curve. This behavior was probably due to progressively increasing amounts of slippage along the critically inclined fractures with increasing load.

3.4 RHYOLITE

The entire core received from Hole MA-CR-29 was petrographically identified as light red fine-grained rhyolite. Most specimens tested contained fractures that ranged in orientation from horizontal to vertical. Several specimens contained vesicles.

A summary of the physical test results is given below. Detailed results are given in Appendix G.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Moderately Fractured and/or Vesicular Core:					
MA-CR-29	9	2.65	52.7	34,550	18,560
	11	2.62	54.0	34,550	17,200
	16	2.67	51.7	37,880	18,220
	18	2.68	--	29,060	18,700
	19	2.68	--	26,700	18,680
	22	2.66	56.8	26,640	17,470
	Average	2.66	53.8	31,560	18,140

(Continued)

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Critically Fractured to Highly Fractured Core:					
MA-CR-29	3	2.65	--	11,700	18,000
	4	2.65	--	14,060	18,160
	7	2.65	53.8	12,420	18,860
	13	2.64	48.3	7,580	18,040
	15	2.64	48.5	6,090	17,260
	Average	2.65	50.2	10,370	18,060

Ultimate uniaxial compressive strengths exhibited by the rhyolite ranged considerably, probably due to variation in nature and degree of fracturing present in the core. Those specimens that were moderately fractured and/or contained vesicles were quite competent, yielding an average ultimate strength of 31,560 psi. Critically oriented fractures and well developed systems of fracture, however, weakened the core substantially, resulting in an average ultimate uniaxial compressive strength of 10,370 psi for this group of specimens. Two of these specimens yielded ultimate strengths in the incompetent range, i.e., less than 8,000 psi.

Compressional wave velocities exhibited by the rhyolite specimens were relatively uniform in magnitude. Nature and degree of fracturing present in the core had no obvious effect on wave velocities,

as those velocities yielded by the critically to highly fractured core covered the same general range as did those exhibited by the moderately fractured and/or vesicular core. Likewise, there was no apparent relation between compressional wave velocity and ultimate uniaxial compressive strength.

As indicated in the tabulation below, elastic constants, particularly the dynamic elastic constants, determined for the rhyolite from this area were also relatively uniform in magnitude. Static values showed somewhat more scatter, but this was to be expected since ultimate uniaxial compressive strengths (an indicator of static moduli) varied considerably, whereas wave velocities (upon which dynamic constants depend) were relatively uniform in value.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
MA-CR-29	3	8.7	7.1	3.4	9,680	0.30
	4	8.7	7.3	3.3	9,680	0.30
	7	9.4	7.9	3.6	10,050	0.30
	9	9.3	7.6	3.6	10,000	0.30
	11	7.8	6.4	3.0	9,220	0.30
	13	8.3	7.4	3.2	9,420	0.31
	15	8.2	6.3	3.2	9,490	0.28
	16	9.0	7.3	3.5	9,800	0.30
	18	9.6	7.7	3.7	10,110	0.29

(Continued)

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests (Continued):						
MA-CR-29	19	9.5	7.7	3.7	10,100	0.29
(Cont'd)	22	7.6	7.2	2.9	8,920	0.32
	Average	8.7	7.3	3.4	9,680	0.30
Static Tests:						
MA-CR-29	3	7.3	6.4	2.8	--	0.31
	11	8.0	4.0	3.4	--	0.16
	16	10.0	8.8	3.8	--	0.31
	Average	8.4	6.4	3.3	--	0.26

Static stress-strain curves revealed that the rhyolite was slightly inelastic and quite brittle. Upon cycling, some hysteresis and residual strain were exhibited.

3.5 BASALT AND GABBRO

Most of the material received from Hole MA-CR-18 was petrographically identified as basalt and gabbro. This material ranged in physical condition from intact or moderately fractured to highly fractured. A summary of the physical test results is given in the following tabulation. Detailed results are given in Appendix E.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Rock Type
				psi	fps	
Intact or Moderately Fractured Core:						
MA-CR-18	3	2.89	--	25,240	15,550	Gabbro
	6	3.00	--	19,240	18,210	Basalt
	18	2.94	--	43,940	17,030	Gabbro
	20	3.00	53.9	34,850	17,780	Basalt
	22	3.01	--	47,420	18,570	Basalt
	24	2.92	51.2	20,150	18,870	Basalt
	27	3.07	53.5	27,880	21,060	Gabbro
	Average	2.98	52.9	31,250	18,250	
Highly Fractured Core:						
MA-CR-18	9	2.98	--	6,360	15,190	Basalt
	16	2.89	--	6,000	16,420	Gabbro
	Average	2.94	--	6,180	15,800	

Physical test results exhibited by the basalt and gabbro from Hole MA-CR-18 were quite varied, the main contributing factor apparently being the nature and degree of fracturing present in the core.

The intact and moderately fractured specimens yielded an average ultimate uniaxial compressive strength of 31,250 psi. The range of strengths exhibited by this group was, however, quite great, i.e. 19,240 to 47,420 psi. Compressional wave velocities were also rather variable, ranging in magnitude from 15,550 to 21,060 fps.

Significantly, the average ultimate uniaxial compressive strength yielded by the highly fractured core was only approximately one-fifth as great as that yielded by the intact and moderately fractured core. Both of the highly fractured specimens exhibited ultimate strengths characteristic of incompetent rock, i.e., less than 8,000 psi.

Elastic constants determined for the basalt and gabbro from this hole were generally rather uniform, as indicated in the tabulation below. Values of the particular constants for the basalt and gabbro did not differ significantly.

Hole No.	Specimen No.	Modulus			Shear Wave Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
MA-CR-18	3	7.6	5.4	3.0	8,770	0.27
	6	8.9	9.0	3.3	9,060	0.34
	9	6.4	6.0	2.4	7,770	0.32
	16	7.6	6.6	2.9	8,660	0.31
	18	8.6	7.1	3.3	9,160	0.30
	20	9.7	7.8	3.8	9,650	0.29
	22	9.7	9.1	3.7	9,520	0.32
	24	9.6	9.2	3.6	9,610	0.33
	27	12.5	12.0	4.7	10,680	0.33
	Average	9.0	8.0	3.4	9,210	0.31
Static Tests:						
MA-CR-18	6	11.4	5.3	5.0	--	0.14
	27	12.5	6.8	5.2	--	0.19
	Average	12.0	6.0	5.1	--	0.17

Static stress-strain curves determined for two specimens revealed these materials to be somewhat inelastic and relatively brittle. Some hysteresis was revealed upon cycling. No residual strain could be detected upon complete removal of the axial load.

CHAPTER 4

SPECIAL TESTS

4.1 EVALUATION OF DEGREE OF ANISOTROPY

Six rock specimens from the Machias study area were selected and prepared for determination of compressional and shear wave velocities according to the ASTM proposed method of test for laboratory determination of ultrasonic pulse velocities and elastic constants of rock. The NX-diameter specimens were cut to lengths of 2 inches and ground on the ends to a tolerance of 0.001 inch. Four 1/2-inch-wide strips were also ground down the sides of the cylindrical surface at 90-degree angles. The velocities, densities, and dimensions were measured as specified in the proposed test method. Results of velocity determinations are given in Table 4.1.

Compressional wave velocities exhibited by the several specimens tested were generally moderate in magnitude and somewhat variable. The variation was probably due to variation in grain size and nature and degree of fracturing present in the core.

Deviations from the average compressional wave velocity, generally thought to be an indication of the relative degree of anisotropy, were moderate to high. Only one specimen, however, exhibited a deviation greater than 6 percent. Significantly, the two porphyritic granites tested from Holes MA-CR-4 and -14 yielded the greatest percent deviations.

A compilation of the elastic properties computed from the compressional and shear wave velocities and the specific gravity is presented in Table 4.2. However, particular discretion must be used in utilizing the moduli results, as experimental errors are introduced when the differences in velocities are significant. The proposed ASTM test method states that the equations for computation of elastic moduli should not be used if "any of the three compressional wave velocities varies by more than 2 percent from their average value. The error in E and G due to both anisotropy and experimental error then does not exceed 6 percent." Naturally, the error is compounded by greater differences in the three-directional velocity measurements, as are present here.

The 2 percent allowable deviation proposed by ASTM appears to be rather unrealistic since laboratory-determined values of compressional and shear wave velocities are reproducible within a deviation from the average of only 2 to 3 percent. Thus, it would appear that the point of division between isotropy and anisotropy would possibly be more realistically in the range of 5 to 8 percent deviation from the average. It should be kept in mind, however, that this greater deviation would also allow a greater error in the computed values of E and G.

4.2 TENSILE STRENGTH

Six NX-diameter rock specimens were selected in an attempt to

represent the variation of rock type present in the cores received from the drill holes in the Machias study area. The specimens were prepared and tested for tensile strength according to the ASTM proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." For comparative purposes, tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens. The test results are given in Table 4.3.

Indirect (Brazilian) tensile strengths yielded by the six specimens tested were rather uniform, ranging from 660 to 1,120 psi. In four of the six specimens, indirect strengths were substantially greater than the corresponding direct strengths.

Direct tensile strengths varied considerably, ranging from 100 to 1,650 psi. Two of the lowest direct strengths were exhibited by the black and white porphyritic granites. Expectedly, the greatest direct strength was yielded by the fine-grained rhyolite porphyry. This specimen did not, however, exhibit the greatest indirect strength.

In most cases, the direct tensile strength should better reflect the minimum tensile strength characteristic of a particular rock specimen, since a specimen subjected to direct tension should be more prone to failure at a point of minimum strength, i.e., along fractures, etc. However, in cases in which fractures are oriented vertically, i.e., parallel to the axis of the core, indirect strengths may better reflect the minimum tensile strength of the rock, particularly

if the fractures are not healed. Thus, tensile strength data must be viewed with due consideration given to the nature and degree of fracturing present in the core.

4.3 PETROGRAPHIC EXAMINATION

4.3.1 Core Samples. Seven boxes of NX-size core from Hancock and Washington Counties, Maine, were received for testing in November 1969. Each box contained about 15 feet of core representing several depths to 200 feet.

The cores were inspected to select representative pieces from all significant rock types for petrographic examination. The cores are described below.

(1) Core MA-CR-4 (SAMSO-14, DC-1). The core was black and white, very coarse-grained porphyritic granite. Specimens 3, 5, and 13 were medium-grained, and Specimens 1 through 12 were weathered. Specimen 13 contained a contact between the porphyritic granite and the medium-grained granite. All of the specimens appeared intact.

(2) Core MA-CR-13 (SAMSO-14, DC-2). The entire core was gray medium-grained granite. Specimen 5 was highly fractured and Specimens 4 and 6 through 13 contained minor vertical fractures. Specimens 1 and 2 and 8 through 13 were slightly weathered.

(3) Core MA-CR-29 (SAMSO-14, DC-3). The entire core was light red fine-grained rhyolite. Only Specimens 11 and 16 were free of fractures, but Specimens 9, 10, 12, and 17 through 23 contained

only a few vertical and horizontal fractures. Specimens 11, 13, 16, and 22 contained vesicles.

(4) Core MA-CR-18 (SAMSO-14, DC-4). The core was black medium-grained gabbro, black fine-grained basalt, black and white medium-grained tonalite, and pink and white coarse-grained pegmatite. The bulk of the core was basalt and gabbro that apparently differed only in grain size and not in bulk composition.

Specimen 8 and parts of Specimens 1, 11 through 14, 22, and 24 contained black and white tonalite. In Specimens 22 and 24, the tonalite apparently intruded and included basalt. Specimens 8, 12, 13, and 14 contained fractures. None of the tonalites appeared weathered.

Specimens 24 and 25 contained contacts with the pegmatite, and Specimen 25 also contained minor vertical fractures.

Specimens 2, 6, 9, 15, 20, 21, and parts of Specimens 1, 11, 12, 22, 23, and 24 were fine-grained basalt. Specimens 20 and 21 contained small dikes of gabbro, and Specimens 2, 6, 9, 12, 15, and 20 contained fractures; Specimen 9 was highly fractured.

Specimens 3 through 5, 7, 10, 16 through 19, 26, and 27 and parts of Specimens 13, 14, 23, and 25 were medium-grained gabbro. Specimens 4, 5, 7, 10, 16, 17, 25, and 27 contained fractures; Specimen 16 was highly fractured.

(5) Core MA-CR-14 (SAMSO-14, DC-5). The entire core was black and white, very coarse-grained porphyritic granite that was similar to

the granite from Core MA-CR-4. Specimens 4, 5, 12, 13, 15, and 18 contained closed fractures, and Specimens 9 and 10 were weathered.

(6) Core MA-CR-20 (SAMSO-14, DC-6). The entire core was pink and gray medium-grained granite. Specimens 1, 4, 7, 8, and 12 through 21 contained fractures. The fractures in Specimens 17, 18, and 19 were filled with quartz. Specimens 1, 7, 10, 12, 15, 16, 20, and 21 were weathered.

(7) Core MA-CR-12 (SAMSO-14, DC-7). The entire core was pink and gray medium-grained granite similar to the granite in Core MA-CR-20. All the specimens except Specimen 21 contained vertical or horizontal fractures, and Specimens 3, 6, and 13 contained critically oriented fractures.

4.3.2 Specimens Selected for Examination. The specimens selected for petrographic examination were as follows:

Core No.	CD Serial No.	Specimen No.	Approximate Depth	Rock Description
			feet	
MA-CR-4	SAMSO-14, DC-1	10	81	Black and white, very coarse-grained porphyritic granite
MA-CR-13	SAMSO-14, DC-2	10	89	Gray medium-grained granite
MA-CR-29	SAMSO-14, DC-3	12	104	Light red fine-grained rhyolite

(Continued)

Core No.	CD Serial No.	Specimen No.	Approximate Depth	Rock Description
			feet	
MA-CR-18	SAMSO-14, DC-4	1	7	Contact of a black fine-grained basalt and black and white medium-grained tonalite
		4	32	Black and white medium-grained gabbro
		23	169	Black and white medium-grained gabbro intruding and including black fine-grained basalt
		26	190	Black medium-grained gabbro
MA-CR-20	SAMSO-14, DC-6	5	42	Pink and gray medium-grained granite

4.3.3 Test Procedure. Each specimen was sawed axially yielding two sections. The sawed surface of one section of each specimen was polished and photographed. Composite samples were obtained from the whole length or from selected portions from the unpolished section. The composite samples were ground to pass a No. 325 sieve (44 μm). X-ray diffraction (XRD) patterns were made of each sample as a tightly packed powder. All XRD patterns were made using an XRD-5 diffractometer with nickel-filtered copper radiation. The samples X-rayed are listed as follows:

Core No.	CD Serial No.	Section No.	Description of X-Ray Sample
MA-CR-4	SAMSO-14, DC-1	10	Entire length of core
MA-CR-13	SAMSO-14, DC-2	10	Entire length of core
MA-CR-29	SAMSO-14, DC-3	12	Entire length of core
MA-CR-18	SAMSO-14, DC-4	1a	Black fine-grained basalt
		1b	Tonalite inclusion in the basalt
		4	Entire length of core
		23a	Black and white gabbro
		23b	Basalt inclusion in the gabbro
		26	Entire length of core
MA-CR-20	SAMSO-14, DC-6	5	Entire length of core

Small portions of the powdered samples were tested with dilute hydrochloric acid and with a magnet to determine whether carbonate minerals or magnetite were present.

Each polished section was examined with a stereomicroscope. Thin sections were prepared from each unpolished section of core and examined with a polarizing microscope. A point-count modal analysis was made on each thin section in which a count was made at 500 points.

4.3.4 Results. According to the system presented in Reference 2, the cores examined from the Machias area can be divided into

the five following groups: granite, rhyolite, tonalite, gabbro, and basalt. Granite was the most abundant rock type, as it made up all but two of the cores. The porphyritic granites (Cores MA-CR-4 and -14) were taken from late Devonian intrusives that form the Lucerne pluton. The granites from Cores MA-CR-12 and -13 were taken from the Tunk Lake pluton (Reference 3). The granites from Core MA-CR-20 and the gabbros, basalts, and tonalites from Core MA-CR-18 were taken from the Bays of Maine complex of southeastern Maine (Reference 4). The rhyolite was a fine-grained phase of the Red Beach granite. All of these rocks represent middle Paleozoic intrusives that range from middle Sibrian to late Devonian in age. The oldest rocks appear to be those associated with the Bays of Maine complex. The rocks from the Lucerne pluton are regarded as next oldest, followed by the porphyritic granite from the Tunk Lake pluton. The rhyolite from the Red Beach granite is believed to be the youngest rock examined (Reference 5). The modal compositions of each rock type are summarized in Tables 4.4 and 4.5, and the bulk compositions, based on XRD results, are summarized in Tables 4.6 and 4.7. The sections selected for petrographic examination are discussed below.

(1) <u>Granites (Cores MA-CR-4, -12, -13, -14, and -20)</u>. These rocks ranged from medium-grained to very coarse-grained porphyritic granite. The major constituents were quartz, microcline, and plagioclase. The feldspars were perthitic in most of the granites.

(a) Section 10 of Core MA-CR-4 (SAMSO-14, DC-1). This section was black and white, very coarse-grained porphyritic granite (Figure 4.1) that was typical of the granites from the Lucerne pluton (Cores MA-CR-4 and -14). The section contained almost equal amounts of quartz, plagioclase with an anorthite content of 9 percent (albite), and microcline. These minerals made up almost 90 percent of this section (Table 4.4). Biotite was the most abundant ferromagnesian mineral in the section. Microcline was strongly perthitic and unaltered, and plagioclase was slightly altered to sericite. The section was very fresh and contained a few minor microfractures.

(b) Section 10 of Core MA-CR-13 (SAMSO-14, DC-2). The section was a gray medium-grained granite and was representative of the granites from the Tunk Lake pluton (Cores MA-CR-12 and -13). This section had been fractured and altered (Figure 4.1). Quartz and perthitic feldspar were the major constituents. XRD results indicated that the perthite was approximately 50 percent plagioclase and 50 percent potash feldspar. The major alteration product in the section was a mixed-layer clay that appeared to have been formed from the alteration of biotite. Small amounts of calcite were associated with the clay. Microfractures were common throughout the section.

(c) Section 5 of Core MA-CR-20 (SAMSO-14, DC-6). The section was a pink and gray medium-grained granite. It contained a few horizontal fractures, and no primary structure was apparent (Figure 4.2).

Plagioclase, with an anorthite content of 36 percent, often exhibited compositional zoning, with the anorthite content ranging from 25 percent in the center of the phenocryst to 36 percent at the outer edge. Perthite microcline was common in the section. Biotite was slightly altered to chlorite and magnetite. Several quartz, plagioclase, and microcline grains had been bent or broken. The microfractures were often sealed with calcite.

(2) Rhyolites of Core MA-CR-29 (SAMSO-14, DC-3). All of Core MA-CR-29 was rhyolite; no rhyolite was present in the other cores. Section 12, a red fine-grained rhyolite (Figure 4.2), was representative of these rhyolites. This section contained no apparent primary structures but did contain minor horizontal fractures. Zoned plagioclase, with an anorthite content of 40 percent (andesine), had been strained and altered to sericite. Orthoclase was also altered but not so severely as was the plagioclase. Biotite was almost completely altered to chlorite. Calcite and hematite had been introduced along fractures.

(3) Tonalites of Parts of Core MA-CR-18 (SAMSO-14, DC-4). These black and white medium-grained rocks comprised about 10 percent of Core MA-CR-18. Section 1 of Core MA-CR-18 contained basalt and tonalite. The tonalite was typical of the tonalites from this area. Plagioclase, with an anorthite content of 44 percent, and quartz formed the bulk of the rock. The sample was fractured, but most of

the fractures had healed. Alteration was greatest along the healed fractures, with plagioclase altering to sericite and biotite to chlorite.

(4) Gabbros and Basalts of Parts of Core MA-CR-18 (SAMSO-14, DC-4). These rocks, which ranged from fine-grained basalts to medium-grained gabbros, were similar in composition. Plagioclase, with an anorthite content near 50 percent (labradorite), hornblende, and biotite were the primary constituents of these rocks. Most of the sections contained fractures. Several contained intrusions of tonalite. The amounts of gabbro and basalt in Core MA-CR-18 were about equal, each comprising about 40 percent of the core.

(a) Section 1a of Core MA-CR-18 (SAMSO-14, DC-4). This section contained the contact between black fine-grained basalt and a black and white medium-grained tonalite. The intrusive relation of the tonalite and the basalt had been obscured by folding, which disrupted the contact (Figure 4.3). The basalt had a microscopic foliation that ranged from vertical to horizontal and was cut by several narrow tightly sealed vertical fractures. Plagioclase with an anorthite content of 60 percent and hornblende were the major constituents of the basalt. Epidote was present as a low-grade metamorphic product.

(b) Section 4 of Core MA-CR-18 (SAMSO-14, DC-4). This section contained a faulted contact between the basalt and gabbro

(Figure 4.3). Both rocks were sheared and recrystallized. Pyrite and chlorite were common along shear fractures. The rocks had similar compositions, both consisting primarily of plagioclase with an anorthite content of 58 percent and hornblende. There was very little alteration except along shear fractures. Both rocks contained a low-angle foliation that was cut by the fractures.

(c) Section 23 of Core MA-CR-18 (SAMSO-14, DC-4). This section was medium-grained gabbro with many inclusions of basalt (Figure 4.4). The modal and bulk compositions of the two rocks were similar (Tables 4.5 and 4.7). The basalt was recrystallized, but the gabbro was not. In both rocks, plagioclase with an anorthite content of 55 percent exhibited minor granulation and alteration along grain boundaries. Epidote was a common metamorphic product in the basalt.

This section indicates that the basalt was older than the gabbro, although the difference in age was possibly small, as the similarity in composition suggests both rocks were derived from the same magma.

(d) Section 26 of Core MA-CR-18 (SAMSO-14, DC-4). This section was typical of the dark gray medium-grained gabbro in Core MA-CR-18 (Figure 4.4). Plagioclase with an anorthite content of 54 percent (labradorite) was the major constituent of this section. Hornblende, biotite, and magnetite each formed about 10 percent of the section. The rock was slightly altered along fractures. There was no apparent foliation or primary flow structures.

4.3.5 Summary. Petrographic examination of eight sections of core from seven holes in the Machias area of southeastern Maine indicated that there were five rock types represented: granite, rhyolite, tonalite, gabbro, and basalt. The granites were the most abundant rock type in the cores examined. The mineral compositions of each rock type are summarized in Tables 4.4 through 4.7, and the sections examined are illustrated in Figures 4.1 through 4.4.

TABLE 4.1 VELOCITY DETERMINATIONS

		Wave Velocity	
		Compressional[a]	Shear[a]
		fps	fps
Hole MA-CR-4, Specimen 20:			
Porphyritic Granite		15,830	8,350
Depth: 165 feet		16,850	8,380
Specific Gravity: 2.67		15,220	8,380
Compressional Deviation[b]: 5.5 pct			
	Average	15,970	8,370
Hole MA-CR-12, Specimen 4:			
Fractured, Medium-Grained Granite		18,100	9,260
Depth: 33 feet		18,010	9,370
Specific Gravity: 2.63		16,630	9,010
Compressional Deviation[b]: 5.4 pct			
	Average	17,580	9,210
Hole MA-CR-14, Specimen 16:			
Phorphyritic Granite		12,310	7,300
Depth: 150 feet		16,310	6,920
Specific Gravity: 2.66		17,970	7,340
Compressional Deviation[b]: 21.6 pct			
	Average	15,470	7,190
Hole MA-CR-18, Specimen 17:			
Medium-Grained Gabbro		18,520	9,610
Depth: 110 feet		18,180	9,510
Specific Gravity: 2.88		17,300	9,140
Compressional Deviation[b]: 3.9 pct			
	Average	18,000	9,420
Hole MA-CR-20, Specimen 2:			
Medium-Grained Granite		18,320	9,430
Depth: 14 feet		17,830	9,380
Specific Gravity: 2.62		17,950	9,440
Compressional Deviation[b]: 1.6 pct			
	Average	18,030	9,420
Hole MA-CR-29, Specimen 20:			
Fractured, Fine-Grained Rhyolite		18,260	9,730
Depth: 173 feet		17,070	9,700
Specific Gravity: 2.68		17,160	9,830
Compressional Deviation[b]: 4.3 pct			
	Average	17,500	9,750

[a] First velocity listed is in axial (longitudinal) direction; other two are on mutually perpendicular diametral (lateral) axes.
[b] Maximum percent deviation from the average of the compressional wave velocity.

TABLE 4.2 DYNAMIC ELASTIC PROPERTIES

Hole No.	Specimen No.		Moduli			Poisson's Ratio
			Young's	Shear	Bulk	
			10^6 psi	10^6 psi	10^6 psi	
4	20		6.6	2.5	5.7	0.31
			6.8	2.5	6.8	0.34
			6.5	2.5	4.9	0.28
		Average	6.6	2.5	5.8	0.31
12	4		8.0	3.0	7.5	0.32
			8.2	3.1	7.3	0.31
			7.4	2.9	6.0	0.29
		Average	7.9	3.1	6.9	0.31
14	16		4.6	1.9	2.7	0.22
			4.8	1.7	7.2	0.39
			5.4	1.9	9.0	0.40
		Average	4.9	1.8	6.3	0.34
18	17		9.4	3.6	8.5	0.32
			9.2	3.5	8.2	0.31
			8.5	3.2	7.3	0.31
		Average	9.0	3.4	8.0	0.31
20	2		8.3	3.1	7.7	0.32
			8.1	3.1	7.1	0.31
			8.2	3.2	7.2	0.31
		Average	8.2	3.1	7.3	0.31
29	20		8.9	3.4	7.5	0.30
			8.6	3.4	6.0	0.26
			8.8	3.5	6.0	0.26
		Average	8.8	3.4	6.5	0.27

TABLE 4.3 TENSILE STRENGTH DETERMINATIONS

Hole No.	Specimen No.	Depth	Tensile Strength		Core Description
			Splitting	Direct	
		feet	psi	psi	
MA-CR-4	20	165	860	360	Black and white porphyritic granite
MA-CR-12	4	33	1,120	1,290	Fractured medium-grained granite
MA-CR-14	16	150	720	100	Black and white porphyritic granite
MA-CR-18	17	110	860	390	Medium-grained granite
MA-CR-20	2	14	660	170	Medium-grained granite
MA-CR-29	20	173	840	1,650	Fractured fine-grained rhyolite

TABLE 4.4 MODAL COMPOSITION OF THREE GRANITES, A RHYOLITE, AND A TONALITE FROM THE MACHIAS AREA, MAINE

Composition is based on count at 500 points in each thin section.

Constituent	Percent of Constituent in Indicated Cores				
	Core MA-CR-4 (SAMSO-14, DC-1) Section 10	Core MA-CR-13 (SAMSO-14, DC-2) Section 10	Core MA-CR-20 (SAMSO-14, DC-6) Section 5	Core MA-CR-29 (SAMSO-14, DC-3) Section 12	Core MA-CR-18 (SAMSO-14, DC-4) Section 13
Quartz	29	26	27	25	38
Orthoclase	--	29	--	29	--
Microcline	30	--	29	--	--
Plagioclase	30	28	31	35	40
Biotite	10	--	11	--	12
Hornblende	--	4	--	--	2
Magnetite	Trace	Trace	Trace	Trace	Trace
Apatite	Trace	Trace	Trace	Trace	Trace
Chlorite	Trace	1	Trace	6	6
Epidote	Trace	Trace	--	Trace	2
Hematite	Trace	--	--	2	--
Calcite	--	Trace	Trace	1	--
Clay	--	9[a]	--	--	--
	Percent of Anorthite Content in Plagioclase				
	9	21	36	40	44
	(Granite)	(Granite)	(Granite)	(Rhyolite)	(Tonalite)

[a] Expandable mixed-layer clay that filled many vertical fractures.

TABLE 4.5 MODAL COMPOSITION OF THREE BASALTS AND TWO GABBROS FROM THE MACHIAS AREA, MAINE

Composition is based on a count at 500 points in each thin section.

Constituent	Percent of Constituent in Indicated Sections of Core MA-CR-18 (SAMSO-14, DC-4)				
	Section 1a	Section 4	Section 23a	Section 23b	Section 26
Quartz	3	12	5	6	7
Plagioclase	43	42	48	45	60
Biotite	7	8	26	20	6
Hornblende	40	33	10	14	9
Pyroxene	--	--	--	--	5
Magnetite	1	--	7	1	10
Pyrite	--	2	Trace	Trace	--
Chlorite	Trace	3	2	2	2
Epidote	6	--	1	12	1
Calcite	--	--	Trace	Trace	Trace
	Percent of Anorthite Content in Plagioclase				
	60	58	55	55	54
	(Basalt)	(Basalt)	(Gabbro)	(Basalt)	(Gabbro)

TABLE 4.6 BULK COMPOSITION OF THREE GRANITES, A RHYOLITE, AND A TONALITE FROM THE MACHIAS AREA, MAINE

Composition is based on XRD results.

Constituent	Amount of Constituent in Indicated Cores[a]				
	Core MA-CR-4 (SAMSO-14, DC-1) Section 10	Core MA-CR-13 (SAMSO-14, DC-2) Section 10	Core MA-CR-20 (SAMSO-14, DC-6) Section 5	Core MA-CR-29 (SAMSO-14, DC-3) Section 12	Core MA-CR-18 (SAMSO-14, DC-4) Section 16
Quartz	A	A	A	A	A
Potash Feldspar	A	A	A	A	--
Plagioclase	A	A	A	A	A
Biotite	A	--	A	--	A
Hornblende	--	Trace	--	--	Trace
Chlorite	--	--	Trace	M	M
Magnetite	Trace	--	Trace	Trace	Trace
Clay	--	M	--	--	--

[a] A = abundant; M = minor.

TABLE 4.7 BULK COMPOSITION OF THREE BASALTS AND TWO GABBROS FROM THE MACHIAS AREA, MAINE

Composition is based on XRD results.

Constituent	Amount of Constituent in Indicated Sections of Core MA-CR-18 (SAMSO-14, DC-4)[a]				
	Section 1a	Section 4	Section 23a	Section 23b	Section 26
Quartz	Trace	M	M	M	M
Plagioclase	A	A	A	A	A
Biotite	M	M	A	A	M
Hornblende	A	A	M	M	M
Pyroxene	--	--	--	--	M
Magnetite	Trace	--	M	Trace	M
Pyrite	--	Trace	--	--	--
Chlorite	Trace	Trace	Trace	Trace	Trace
Epidote	M	--	--	M	--

[a] A = abundant; M = minor.

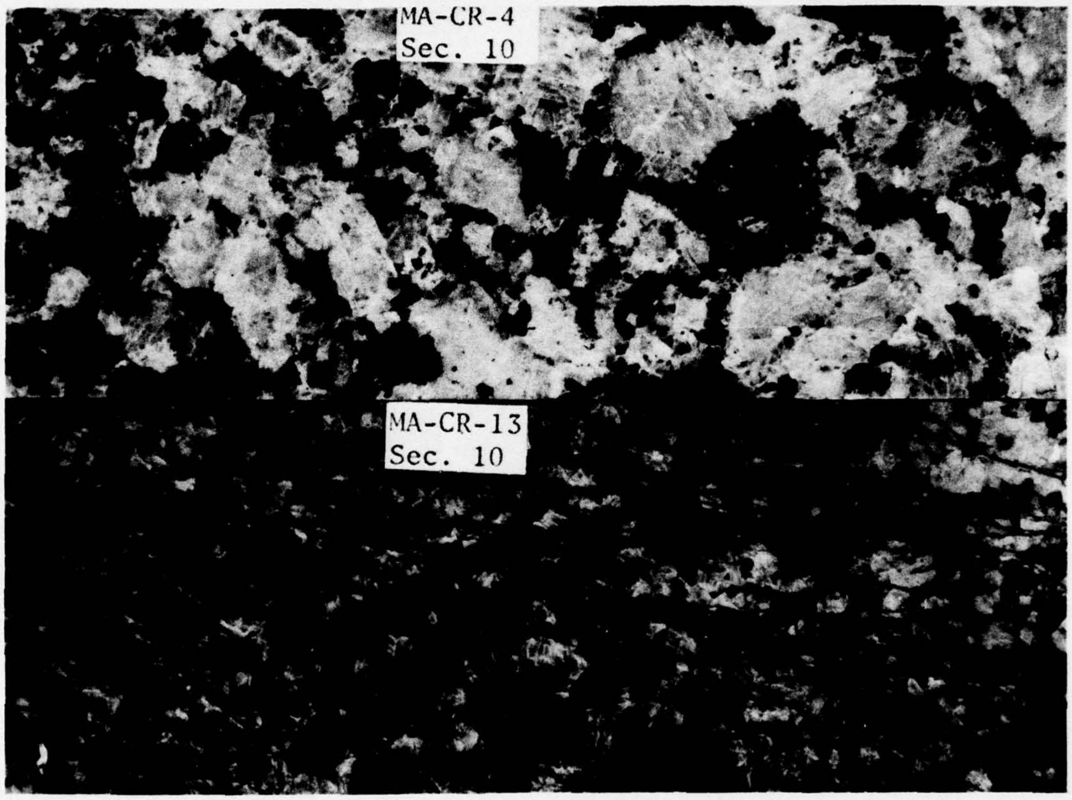


Figure 4.1 Section 10 of Cores MA-CR-4 and -13. Section 10 of Core MA-CR-4 shows a very coarse-grained porphyritic texture of this granite. The black grains are biotite, and the large white grains are phenocrysts of plagioclase and microcline. Section 10 of Core MA-CR-13 shows an equigranular texture and many vertical fractures. The fractures are sealed with a mixed-layer clay.

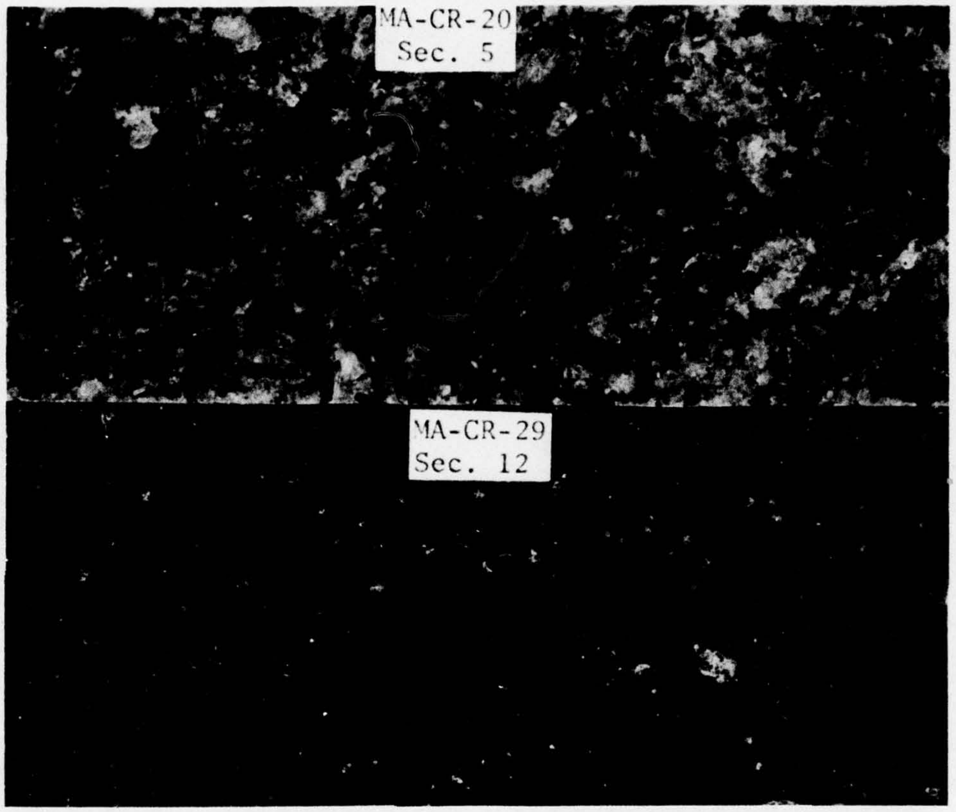


Figure 4.2 Sections 5 and 12 of Cores MA-CR-20 and -29, respectively. Section 5 shows an equigranular texture and several horizontal fractures. Section 12 shows a fine-grained porphyritic texture and is cut and bounded by low-angle fractures.

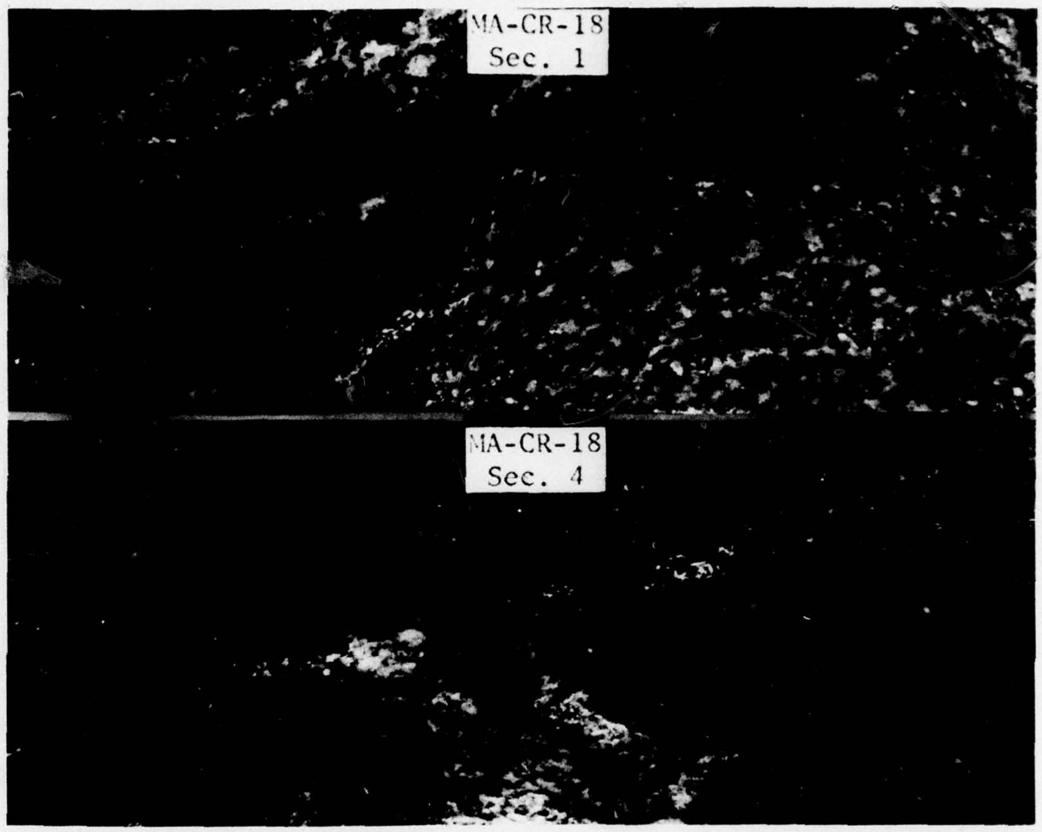


Figure 4.3 Sections 1 and 4 of Core MA-CR-18. Section 1 shows the contact between a basalt and a medium-grained tonalite. The intrusive relation of the tonalite was obscured by a period of folding after intrusion of the tonalite; the relation is unequivocal in other sections. Section 4 contains a faulted contact, the narrow, low-angle line between the basalt and the gabbro. The white area is a folded, quartz-feldspar inclusion in the basalt.

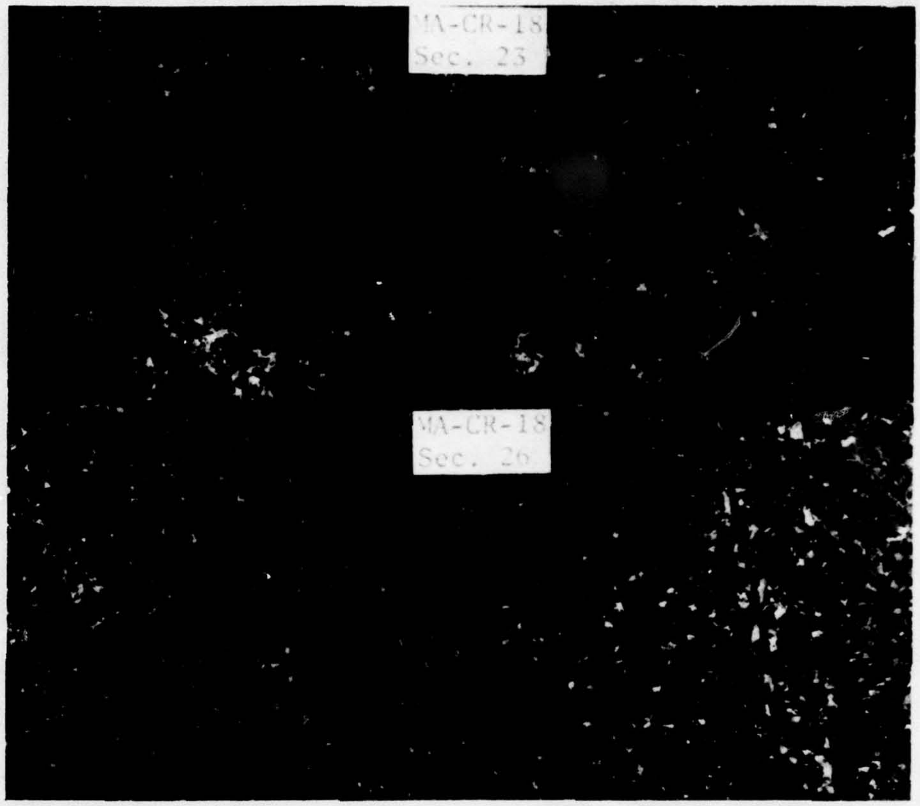


Figure 4.4 Sections 23 and 26 of Core MA-CR-18. Section 23 shows medium-grained gabbro with several basalt inclusions. This section indicates that the basalt is the older of these two related rocks. Section 26 shows the typical equigranular texture of the gabbro. To the right of the label is a healed horizontal fracture.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

The nature of the objective of these rock quality tests dictates overall evaluation of the cores on a hole-to-hole basis. In the instances in which individual holes yielded core of only one rock type (i.e., Holes MA-CR-4, -12, -13, -14, -20, and -29), the evaluation of the hole will, of course, be dictated by characteristics of the particular rock type. In those instances, however, in which several rock types were represented in a single hole, the evaluation of the hole will necessarily reflect the quality of the least competent rock type tested. It should be noted here, however, that differences in rock type are not commensurate with nonuniformity as described herein; rather, uniformity is used to describe the physical characteristics of the material.

To facilitate evaluation of the Machias study area in this manner, a rock quality chart (Figure 5.1) was prepared. Ultimate uniaxial compressive strengths depicted on this chart were expressed in one of three categories: poor (<8,000 psi), marginal (8,000 to 12,000 psi), and good (>12,000 psi). Locations of the individual drill holes are shown in Figure 5.2.

5.2 CONCLUSIONS

On the basis of test results yielded by the specimens of rock core received from the Machias study area, the following conclusions are believed warranted:

1. The rock core received from this area is predominantly granite, with lesser amounts of rhyolite, basalt, and gabbro.

2. Many specimens contained fractures that ranged in orientation from horizontal to vertical. Several of the rhyolite specimens contained vesicles.

3. The granite from this area appeared to be of two types: (1) black and white porphyritic granite and (2) pink and gray uniformly medium-grained granite. The porphyritic granite (Cores MA-CR-4 and -14) was generally found to be relatively competent rock, with ultimate uniaxial compressive strengths ranging from approximately 12,000 to 28,000 psi. One specimen from each hole yielded an ultimate strength in the marginal range (8,000 to 12,000 psi). Fracturing appeared to have little, if any, effect on strength characteristics of this rock. On the other hand, weathering seemed to cause a significant reduction in strength in several of the specimens from Core MA-CR-4. The uniformly medium-grained granite yielded by Cores MA-CR-12, -13, and -20 exhibited ultimate uniaxial compressive strengths that ranged from approximately 2,000 to 43,000 psi. This wide range of data, somewhat greater than that exhibited by the porphyritic

granite previously discussed, was probably due principally to the presence of critically oriented fractures, fractures along which weathering had taken place, and well developed systems of fracture in several of the medium-grained specimens. Fractures of this nature were not present in the porphyritic granite. The stronger specimens were either intact or contained horizontal or vertical fractures that appeared to have little effect on strength properties.

Compressional wave velocities determined for the two granites from this area differed appreciably. The porphyritic granites yielded an unusually low average compressional wave velocity of approximately 12,000 fps, and the uniformly medium-grained granite yielded an average compressional wave velocity of approximately 18,000 fps. The low velocities yielded by the porphyritic granite can probably be attributed to the texture of the material.

4. The rhyolite from the Machias study area yielded physical test results comparable to those yielded by the uniformly medium-grained granite previously discussed. Like the medium-grained granite, the rhyolite, in several instances, yielded ultimate uniaxial compressive strengths in the incompetent range (<8,000 psi). In all cases, the specimens that yielded these low strengths contained critically oriented fractures or well developed systems of fracture. Fracturing appeared to have little effect on the magnitude of compressional wave velocities yielded by the rhyolite.

5. The gabbros and basalts from the Machias study area were all removed from Hole MA-CR-18 and exhibited similar physical test results. As was the case with the rock types previously discussed, these materials were rather competent when in the intact or moderately fractured (vertical or horizontal fractures) state, but were incompetent, i.e., ultimate uniaxial compressive strengths were less than 8,000 psi, when in a highly fractured condition. Compressional wave velocities were generally slightly lower than those yielded by the rhyolite and uniformly medium-grained granite, but were substantially higher than those yielded by the porphyritic granite.

6. Elastic constants yielded by the specimens tested from the Machias study area were generally moderate in magnitude. Due to the very low compressional wave velocities yielded by the porphyritic granite, this material exhibited rather low dynamic Young's moduli values. In all cases, elastic constants within the particular groupings discussed were quite consistent in magnitude.

7. The material tested from this area was generally quite brittle, exhibiting little or no plastic deformation immediately prior to catastrophic failure.

8. Cyclic stress-strain curves determined for representative specimens from each hole generally revealed little hysteresis and no appreciable residual strain. The upward concavity over the initial portions of several of the curves was probably the result of void

and/or microcrack closure during the initial stages of loading.

9. Tensile strengths yielded by representative specimens from this area were low to moderate in magnitude, direct strengths generally being somewhat lower than the corresponding strengths yielded by the Brazilian method of test.

10. Deviations from the average of three compressional wave velocities determined in mutually perpendicular directions, generally thought to be an indication of the relative degree of anisotropy typical of a particular material, were moderate to high, with the porphyritic granite expectedly yielding the greatest variations in velocity, and thus, deviations from the average.

11. Evaluation of the materials from the Machias study area on a hole-to-hole basis indicated that the porphyritic granite is quite uniform and rather competent, offering good possibilities as a competent hard rock medium. The uniformly medium-grained granite is somewhat more variable, with one specimen from Hole MA-CR-13 (taken at a depth of 39 feet) and several specimens from Hole MA-CR-20 yielding physical test results typical of incompetent rock. The intact medium-grained granite should offer relatively good possibilities as a competent hard rock medium; the highly fractured, medium-grained granite and that containing weathered fracture surfaces were, however, generally incompetent, and, therefore, unsatisfactory. The rhyolite and the basalt and gabbro must also be considered unsatisfactory, as

specimens removed from depths greater than 100 feet from each of these holes exhibited physical characteristics typical of incompetent rock.

The above evaluations have been based on rather limited data. Therefore, a more extensive investigation will be required in order to accurately assess the areas under consideration.

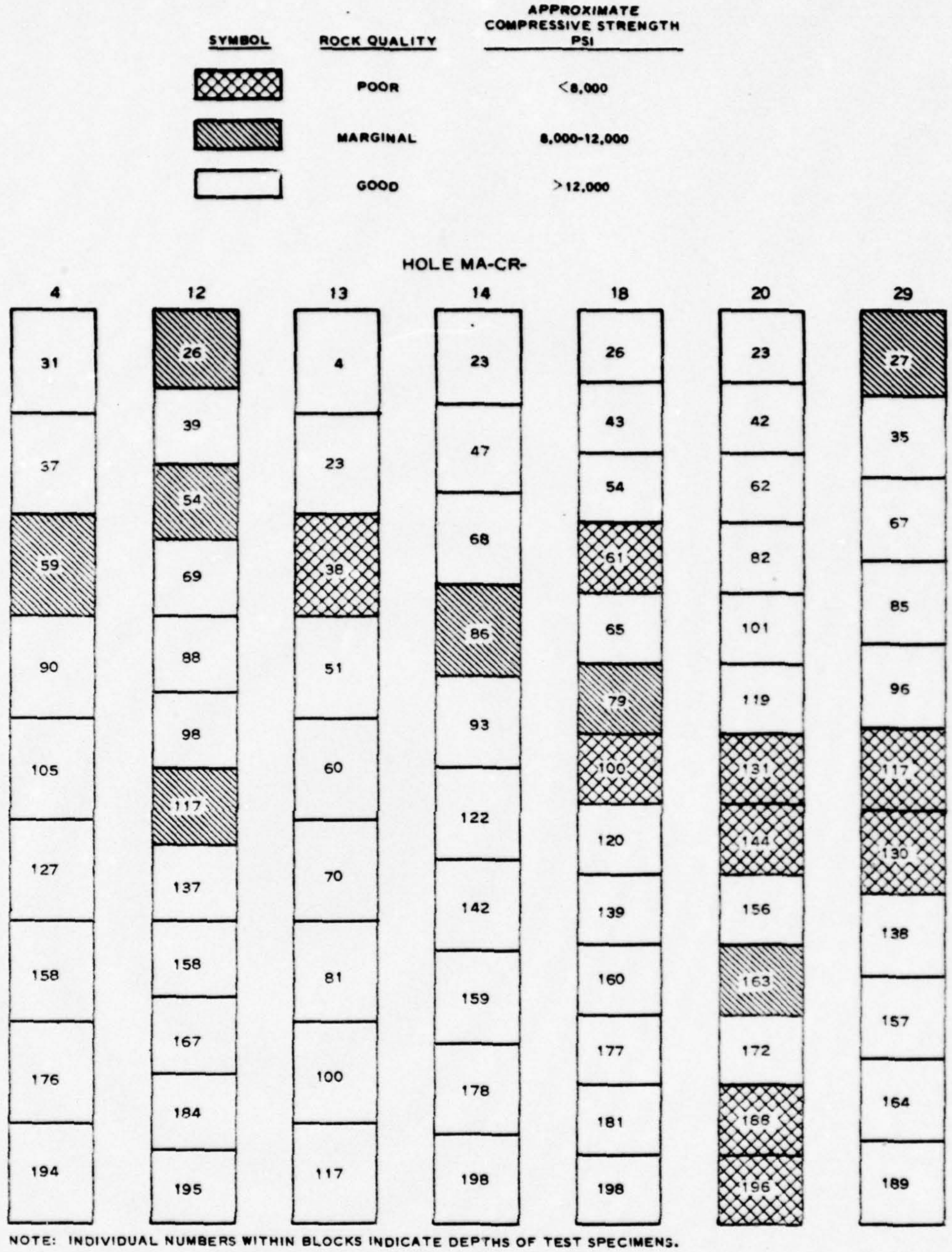
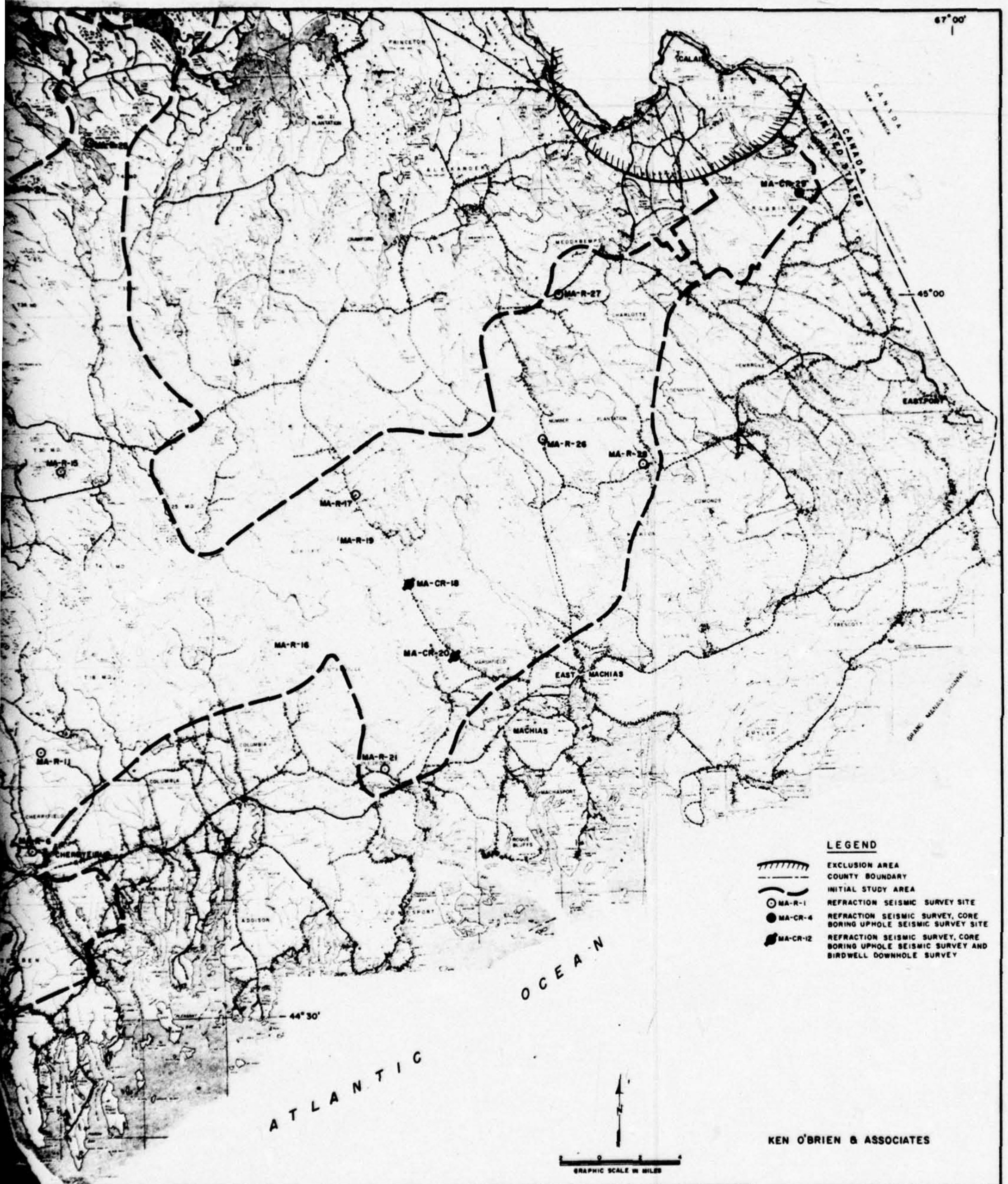


Figure 5.1 Depth versus quality for individual holes.

Figure 5.2 Locations of drill holes.

2



cations of drill holes.

APPENDIX A

DATA REPORT

Hole MA-CR-4

4 December 1969

Hole Location: Hancock County, Maine

Longitude: 68° 09' 27.6" West

Latitude: 44° 51' 33.9" North

Core

1. The following core was received on 17 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	10
2	20
3	31
4	37
5	40
6	49
7	59
8	69
9	76
10	81
11	90
12	98
13	105
14	110
15	119
16	127
17	137
18	148
19	158
20	165
21	176
22	186
23	194

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as black- and white-speckled granite porphyry. Some weathering was evident in the upper reaches of the hole.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Porphyritic Granite	3	Intact, Medium Grained, Limonite Stained	31	2.613	50.4	28,760	15,220
"	4	Coarse Grained, Weathered	37	2.644	49.6	13,330	12,190
"	7	Coarse Grained, Weathered	59	2.605	--	10,760	10,870
"	11	Coarse Grained, Weathered	90	2.633	50.7	12,760	10,670
"	13	Intact, Contact Between Medium- and Coarse-Grained Material	105	2.640	52.8	22,030	15,230
"	16	Intact, Coarse Grained	127	2.636	51.4	20,330	10,550
"	19	Intact, Coarse Grained	158	2.652	57.2	27,420	14,540
"	21	Intact, Coarse Grained	176	2.648	55.8	20,970	16,150
"	23	Intact, Coarse Grained	194	2.674	53.2	22,730	13,810
	Average of Weathered Specimens (3)			2.627	50.1	12,280	11,240
	Average of Unweathered Specimens (6)			2.644	53.5	23,710	14,250

4. The Schmidt hammer test was not conducted on several specimens due to possibility of breakage. The material from this hole exhibited physical test results which formed two distinct groups: one group comprised of the weathered rock, the other comprised of unweathered specimens which exhibited higher physical test results in all four tests utilized.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 3, 13, and 23. Stress-strain curves are given in plates 1, 2, and 3. All three specimens were cycled at 10,000 psi. Results are given below.

Specimen	Modulus, psi x 10^6			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
		Dynamic Tests			
3	6.3	4.9	2.5	8360	0.28
4	4.8	2.6	2.0	7520	0.19
7	3.5	2.3	1.4	6300	0.25
11	3.7	1.9	1.6	6680	0.18
13	5.9	5.2	2.3	7970	0.31
16	3.2	2.2	1.3	5990	0.26
19	5.9	4.5	2.3	8040	0.28
21	6.3	6.1	2.4	8160	0.33
23	6.0	3.6	2.5	8270	0.22

(Continued)

(Continued)

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
			Static Tests		
3	7.1	3.3	3.1	--	0.13
13	7.5	3.9	3.2	--	0.18
23	7.5	3.6	3.3	--	0.15

The unweathered material was quite brittle, exhibiting some hysteresis and slight residual strain. Unfortunately, no specimens of the weathered material were selected for static testing.

Conclusions

6. The core received for testing from hole MA-CR-4 was relatively uniform, identified by the field log received with the core as black- and white-speckled granite porphyry. Some weathering was evident in the upper reaches of the hole. The weathered material, represented by specimens 4, 7, and 11, was significantly weaker than the unweathered rock, exhibiting uniaxial compressive strengths of approximately 50 percent of the unweathered core. Compressional wave velocities were comparatively low for the better material and unusually low for the weathered rock. Moduli exhibited by the material from this hole were also rather low.

Property	Weathered Core	Unweathered Core
Specific Gravity	2.627	2.644
Schmidt Number	50.1	53.5
Compressive Strength, psi	12,280	23,710
Compressional Wave Velocity, fps	11,240	14,250
Static Young's Modulus, psi x 10^6	--	7.4
Dynamic Young's Modulus, psi x 10^6	4.0	5.6

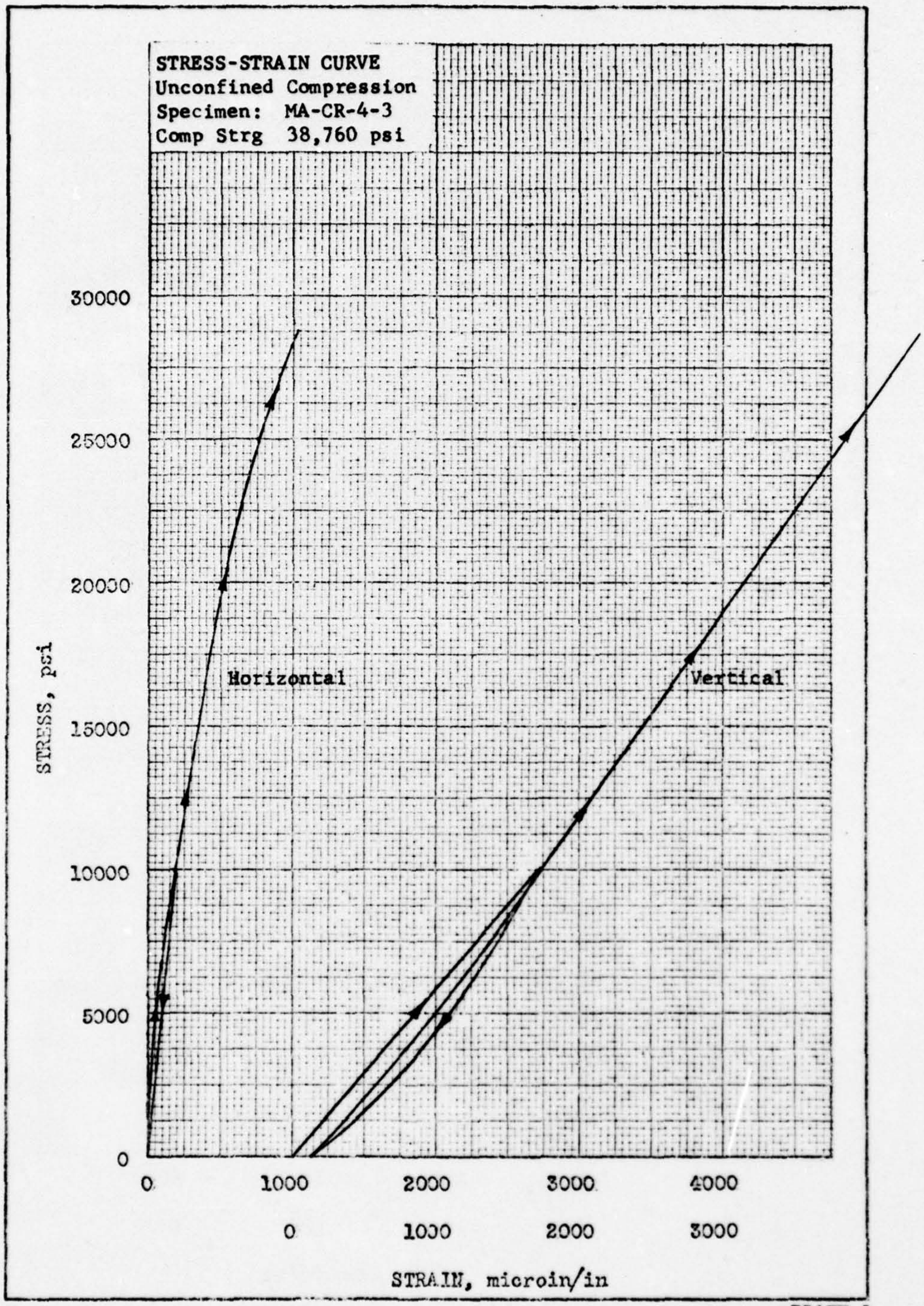
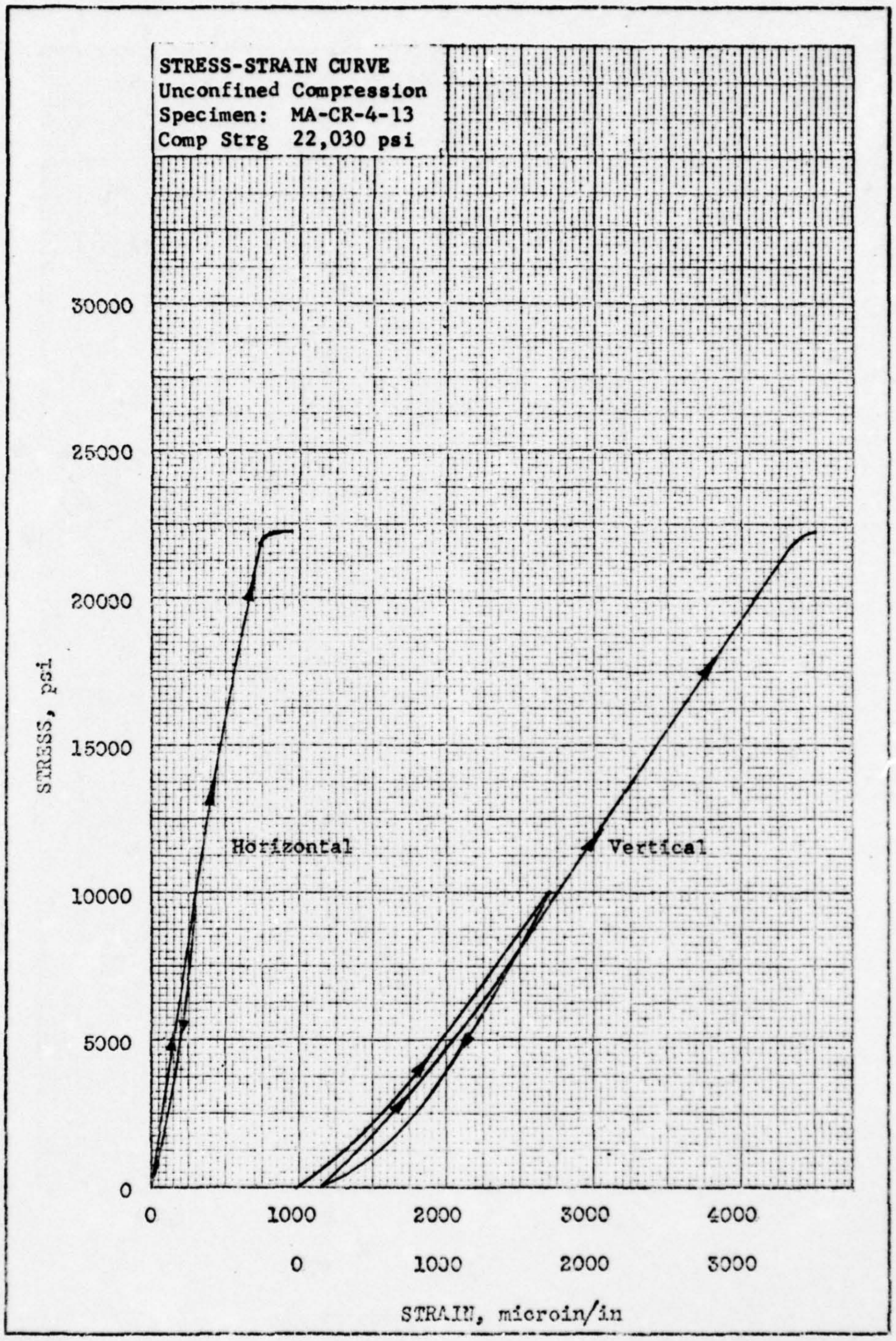

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-4-3
Comp Strg 38,760 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1


STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-4-13
Comp Strg 22,030 psi
STRESS, psi
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25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

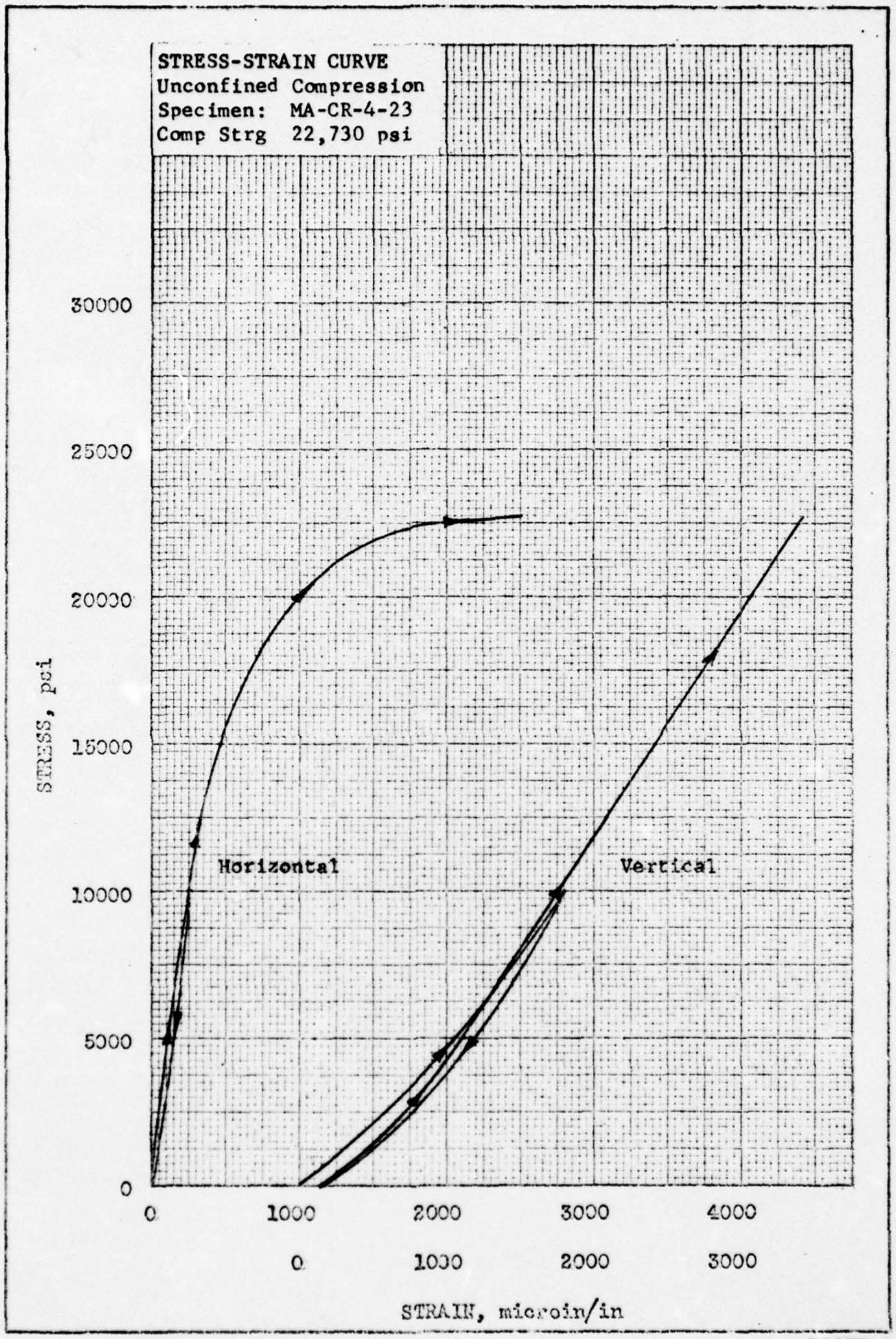

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-4-23
Comp Strg 22,730 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 3

APPENDIX B

DATA REPORT

Hole MA-CR-12

10 December 1969

Hole Location: Washington County, Maine

Longitude: 67° 57' 54" West

Latitude: 44° 33' 16" North

Core

1. The following core was received on 1 December 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	5
2	15
3	26
4	33
5	39
6	54
7	60
8	69
9	79
10	88
11	98
12	108
13	117
14	125
15	137
16	148
17	158
18	167
19	178
20	184
21	195

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as medium-grained, gray to pink granite, similar to the granite from hole MA-CR-20. All specimens except No. 21 contained fractures, most of which were tightly closed.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.*	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Medium-grained granite	3	Contained Critically Oriented Fracture	26	2.615	58.4	8,060	16,990
"	5	Vertical Fractures	39	2.653	57.0	37,050	18,770
"	6	Contained Critically Oriented Fracture	54	2.601	57.4	9,470	18,540
"	8	Tightly Closed, Low-Angle Fracture	69	2.602	--	18,180	18,730
"	10	Vertical Fractures	88	2.605	51.8	17,480	17,610
"	11	Low-Angle Fracture Across One Edge	98	2.620	--	26,520	18,770
"	13	Several Critically Oriented Fractures	117	2.620	58.2	10,390	17,620
"	15	Vertical Fractures	137	2.617	57.2	29,090	17,840
"	17	Vertical Fractures	158	2.604	57.9	20,730	17,390
"	18	Horizontal and Vertical Fractures	167	2.619	57.8	43,030	17,970
"	20	Vertical Fractures	184	2.607	56.3	39,330	18,740
"	21	Intact	195	2.614	--	19,700	17,570
Average of Specimens Containing Critically Oriented Fractures (3)				2.612	58.0	9,310	17,720
Average of Remainder of Specimens (9)				2.616	56.3	27,900	18,150

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

Moduli of deformation

4. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 6, 8, and 21. Stress-strain curves are given in plates 1, 2, and 3. Specimens 8 and 21 were cycled at 10,000 psi. Results are given below.

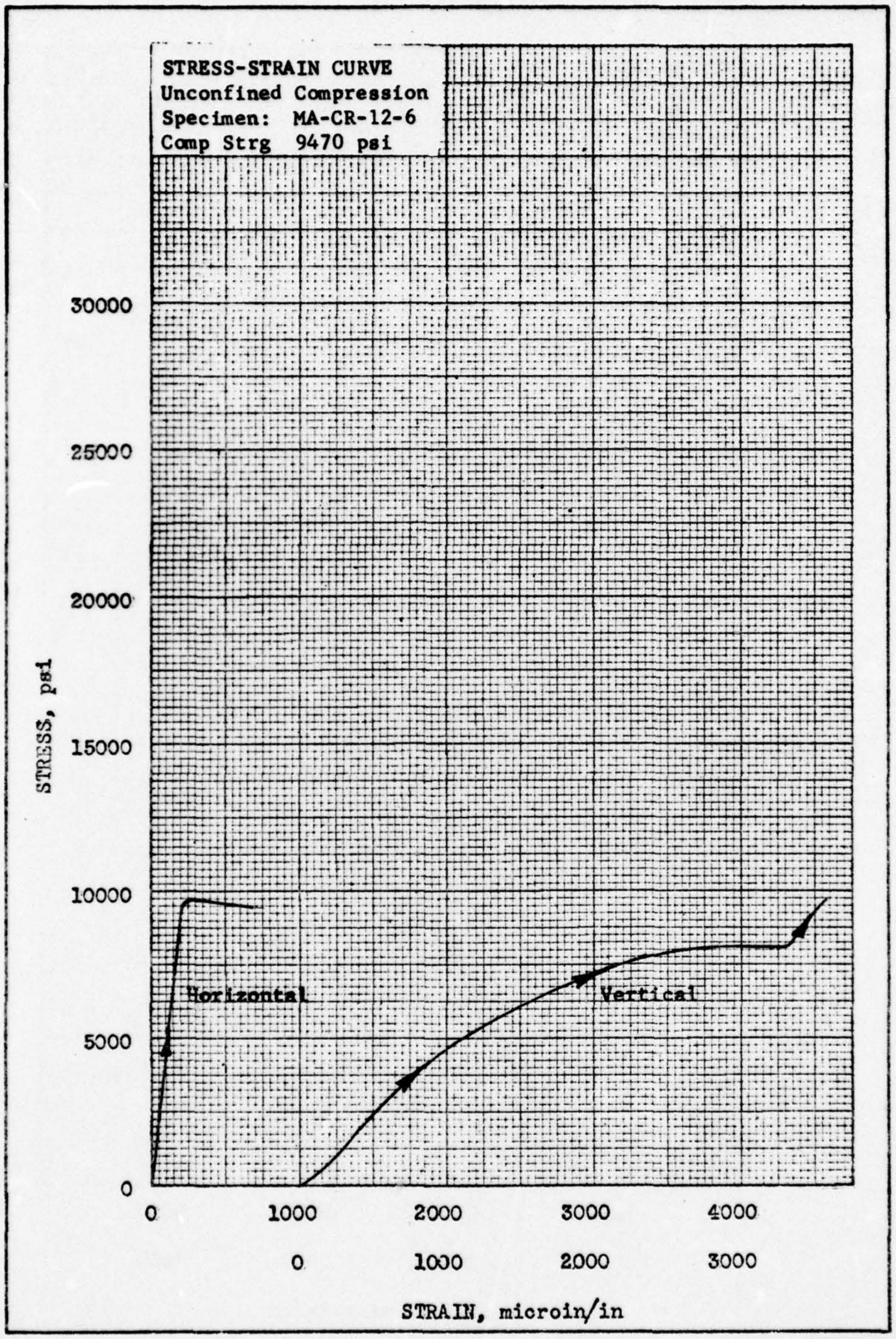
Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	7.3	6.4	2.8	8900	0.31
5	8.8	8.2	3.3	9630	0.32
6	8.6	7.7	3.3	9660	0.31
8	8.3	8.2	3.1	9410	0.33
10	7.8	6.9	3.0	9190	0.31
11	8.8	8.0	3.4	9750	0.32
13	8.0	6.9	3.0	9280	0.31
15	7.5	7.5	2.8	8920	0.33
17	7.6	6.8	2.9	9080	0.31
18	8.6	7.0	3.3	9670	0.30
20	5.3	9.8	1.9	7340	0.41
21	8.1	6.7	3.1	9430	0.30
		Static Tests			
6	3.0	1.2	1.4	--	0.09
8	9.3	4.8	3.9	--	0.18
21	9.3	4.5	4.0	--	0.16

5. The material tested herein, with the exception of the critically fractured core, was quite brittle, exhibiting slight hysteresis and no residual strain. The critically fractured specimen subjected to static tests apparently experienced considerable slippage along the fracture prior to catastrophic failure.

Conclusions

6. **The material received for testing from hole MA-CR-12 was relatively uniform, identified by the field log received with the core as medium-grained, gray to pink granite, similar to that from hole MA-CR-20. All specimens except No. 21 were fractured. Physical test** results indicated the presence of two distinct groups of material, specimens containing critically oriented fractures and specimens containing vertical or horizontal fractures or no fractures at all. The material containing critically oriented fractures was relatively weak, failure occurring along these fractures at low stresses. The remainder of the material from this hole was competent, but exhibited somewhat variable test results. Uniaxial compressive strengths exhibited by this group ranged from 17,000 to 43,000 psi. Dynamic moduli exhibited by the material from this hole were very uniform.

Property	Specimens Containing Critically Oriented Fractures	Remainder of Specimens Tested
Specific Gravity	2.612	2.616
Schmidt Number	58.0	56.3
Compressive Strength, psi	9,310	27,900
Compressional Wave Velocity, fps	17,720	18,150
Static Young's Modulus, psi x 10^6	3.0	9.3


STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-12-6
Comp Strg 9470 psi
STRESS, psi
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25000
20000
15000
10000
5000
0
Horizontal
Vertical
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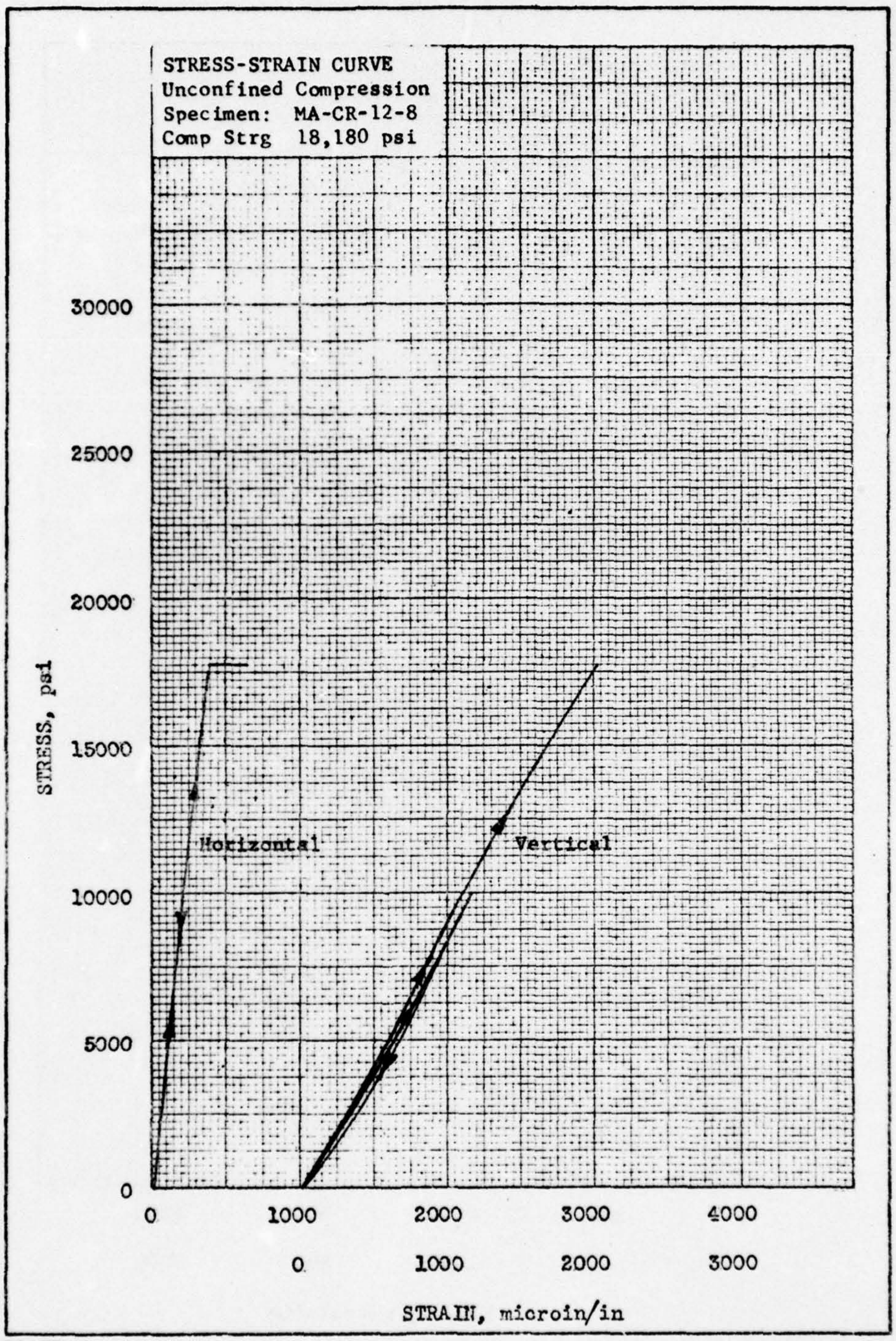
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1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Unconfined Compression
Specimen: MA-CR-12-8
Comp Strg 18,180 psi
STRESS, psi
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25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

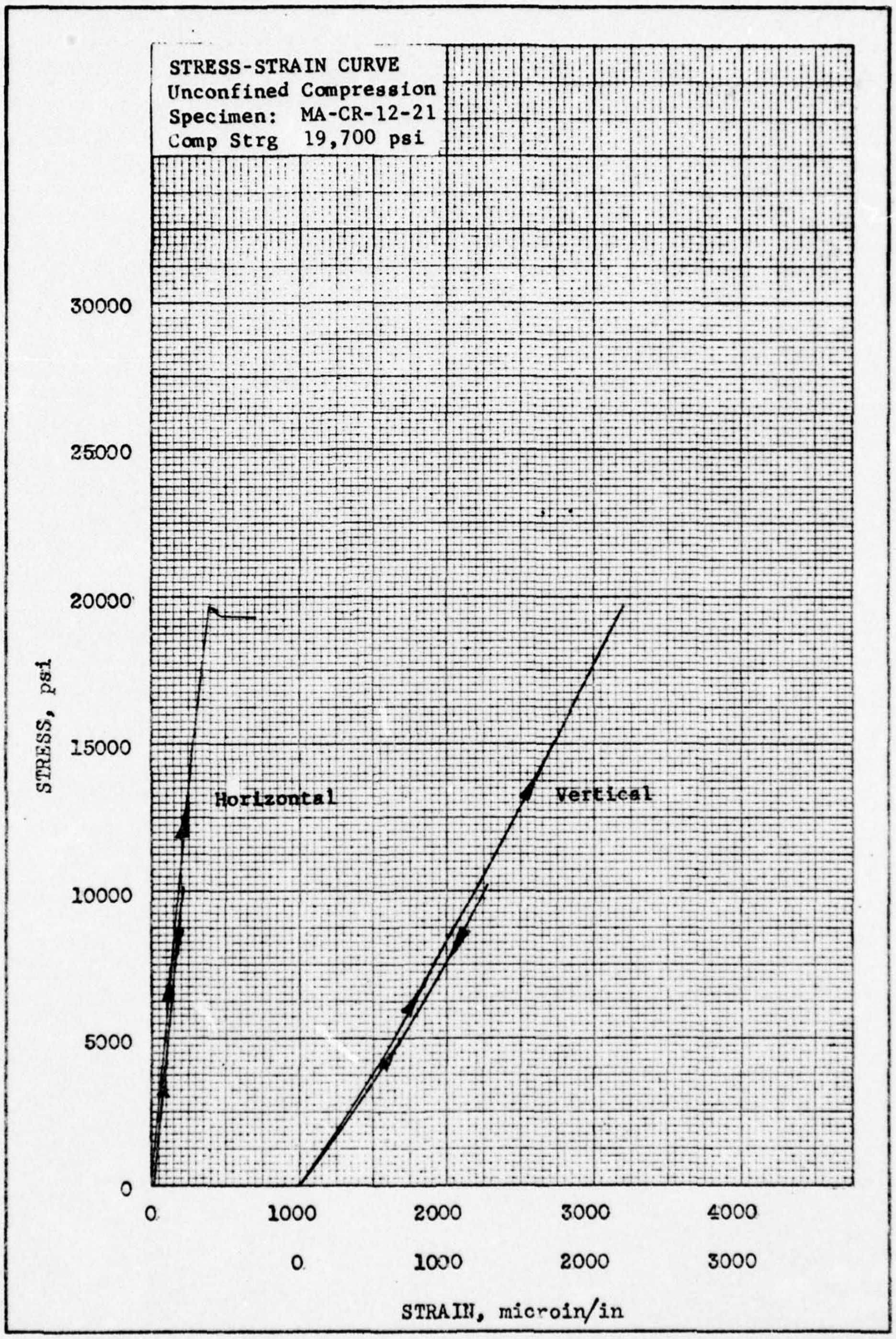
STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-12-21
Comp Strg 19,700 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 3

APPENDIX C

DATA REPORT

Hole MA-CR-13

4 December 1969

Hole Location: Hancock County, Maine

Longitude: 68^{o} 07' 34" West

Latitude: 44^{o} 38' 08" North

Core

1. The following core was received on 20 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	4
2	13
3	23
4	34
5	38
6	51
7	60
8	70
9	81
10	89
11	100
12	108
13	117

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as light-gray to gray quartz monzonite. Specimen Nos. 5, 6, 7, 8, 9, 10, 11, and 13 contained fractures.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive

strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Medium-grained granite	1	No Noticeable Fractures	4	2.643	49.7	30,550	~~10,140~~
"	3	No Noticeable Fractures	23	2.649	54.0	24,580	~~9,930~~
"	5	Highly Fractured	38	2.562	--	1,970	14,270
"	6	Vertical Fractures	51	2.647	57.3	23,710	16,900
"	7	Vertical Fractures	60	2.650	57.4	24,700	18,170
"	8	Vertical Fractures	70	2.640	53.7	16,240	16,030
"	9	Vertical Fractures	81	2.621	50.6	14,910	14,820
"	11	Vertical Fractures	100	2.639	--	16,110	15,820
"	13	Vertical Fractures	117	2.632	58.8	18,420	17,940
	Highly Fractured Specimen			2.652	--	1,970	14,270
	Unfractured Specimens (2)			2.646	51.8	27,560	10,040
	Specimens Containing Vertical Fractures (6)			2.638	55.6	19,020	16,610

4. The Schmidt hammer test was not conducted on several specimens due to possibility of breakage. There appeared to be good correlation between nature and degree of fracturing present and uniaxial compressive strength. Possibly of greater significance, however, is the general trend toward lower strengths ensuing approximately 65 ft below the ground elevation (begins with specimen No. 3), which corresponds to the elevation of the groundwater table given by the core log. Although all

AD-A035 364 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/7
TESTS OF ROCK CORES, MACHIAS STUDY AREA, MAINE.(U)
AUG 70 R W CRISP
UNCLASSIFIED WES-MP-C-70-16 NL

2 OF 2
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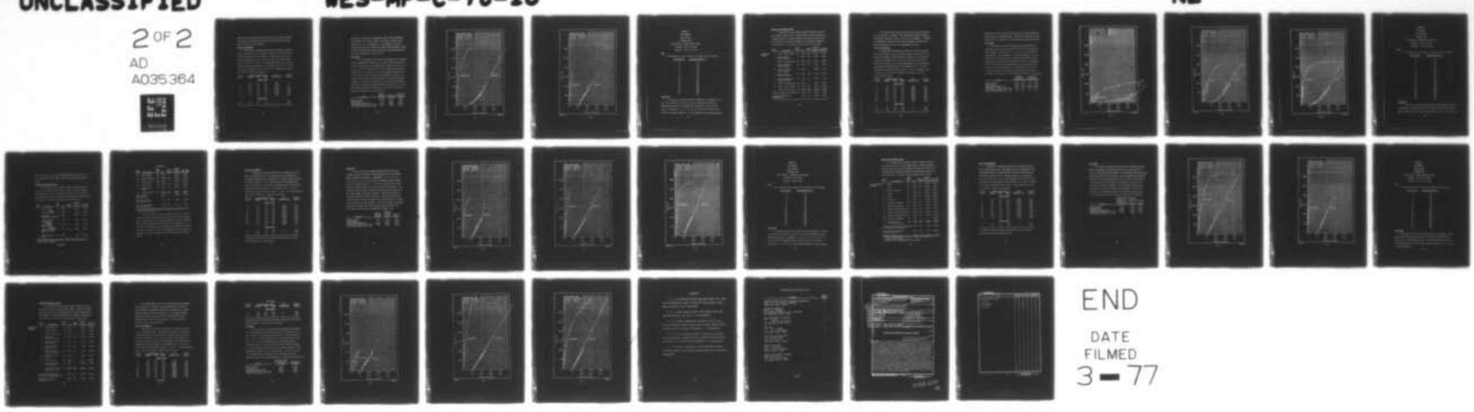
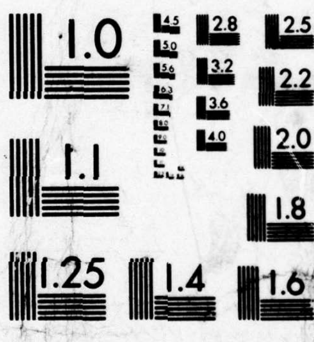
A035364



END
DATE
FILMED
3-77


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

specimens received and tested were surface dry, some moisture may have been present in the vertical fractures or the material may have been altered in situ by the groundwater.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 1 and 13. Stress-strain curves are given in plates 1 and 2. Both specimens were cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
1	3.7	1.2	1.9	7,270	--
3	3.5	1.1	1.8	7,110	--
5	7.0	2.2	3.6	10,210	--
6	7.7	6.2	3.0	9,150	0.29
7	7.9	7.9	3.0	9,090	0.33
8	7.2	5.4	2.8	8,930	0.27
9	6.4	4.3	2.6	8,550	0.25
11	6.9	5.3	2.7	8,720	0.28
13	7.7	7.5	2.9	9,060	0.33
		Static Tests			
1	8.7	3.7	3.9	--	0.11
13	7.8	3.7	3.4	--	0.14

The material tested herein is apparently rather brittle, exhibiting some hysteresis and residual strain. The reverse curvature of the stress-strain curve for specimen No. 13 was probably due to crack closure during the initial phases of loading. Dynamic Poisson's ratios could not be computed for three specimens due to unusually high shear velocity to compressional velocity ratios.

Conclusions

7. The core received for testing from hole MA-CR-13 was relatively uniform in appearance, identified by the field log received with the core as light-gray to gray quartz monzonite. Specimen Nos. 5, 6, 7, 8, 9, 10, 11, and 13 contained fractures, most of which were vertically oriented. With the exception of the highly fractured specimen which was very weak, the core from this hole was generally competent. Predictably, the unfractured specimens exhibited the higher compressive strengths. Of particular significance was the rather obvious general reduction in compressive strengths beginning approximately 65 ft below ground surface elevation, a depth found to correspond to the groundwater table elevation given in the core log.

Property	Highly Fractured Specimen	Unfractured Specimens	Vertically Fractured Specimens
Specific Gravity	2.652	2.646	2.638
Schmidt Number	--	51.8	55.6
Compressive Strength, psi	1,970	27,560	19,020
Compressional Wave Velocity, fps	14,270	10,040	16,610
Static Young's Modulus, psi x 10^6	--	8.7	7.8

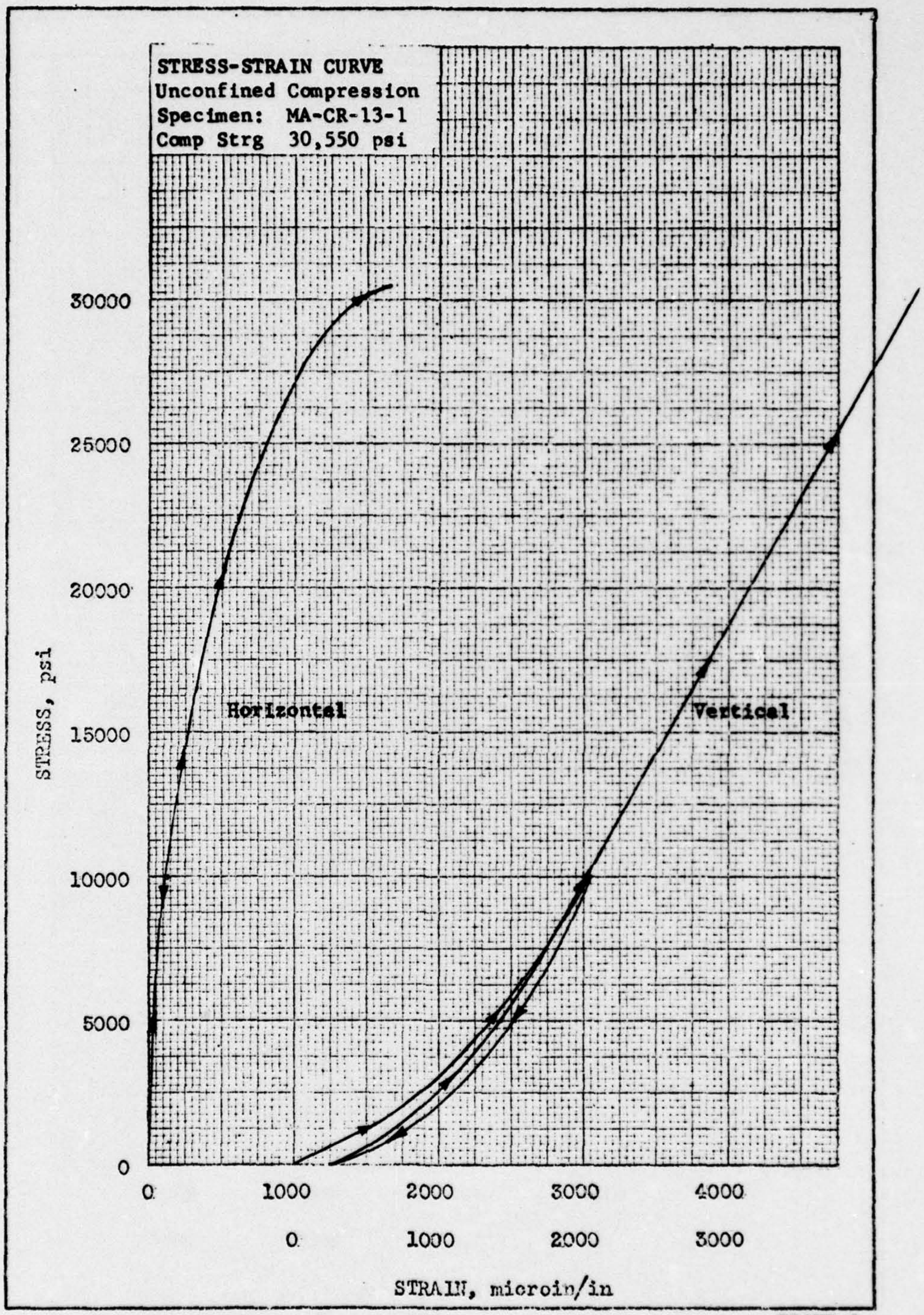

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-13-1
Comp Strg 30,550 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1

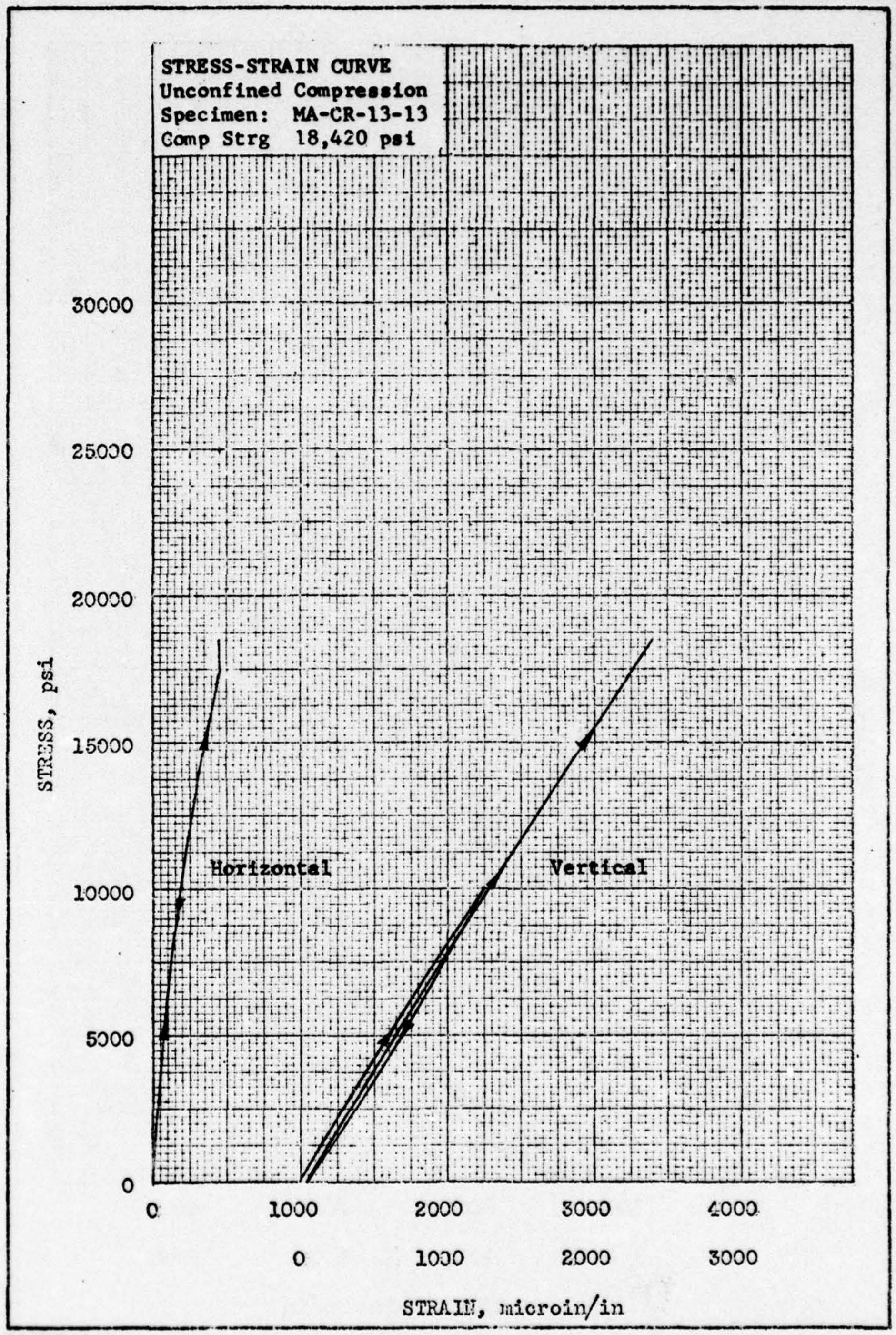

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-13-13
Comp Strg 18,420 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

APPENDIX D

DATA REPORT

Hole MA-CR-14

9 December 1969

Hole Location: Hancock County, Maine

Longitude: 68° 14' 05" West

Latitude: 44° 45' 13" North

Core

1. The following core was received on 25 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	12
2	23
3	30
4	42
5	47
6	58
7	68
8	75
9	86
10	93
11	103
12	116
13	122
14	131
15	142
16	150
17	159
18	170
19	178
20	188
21	198

Description

2. The samples received were uniform in appearance. According to the field log received with the core, the rock was identified as black and white granite porphyry. The material was very similar to that from hole MA-CR-4. Specimen Nos. 4, 5, 12, 13, 15, and 18 contained fractures, most of which were tightly closed; Nos. 9 and 10 appeared to be somewhat weathered.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Porphyritic Granite	2	Intact, Coarse Grained	23	2.666	54.3	20,300	10,970
"	5	Coarse Grained, Vertical Fracture	47	2.664	52.8	18,850	12,400
"	7	Intact, Coarse Grained	68	2.667	48.7	21,300	11,390
"	9	Intact, Weathered, Coarse Grained	86	2.643	43.0	11,060	7,480
"	10	Intact, Weathered, Coarse Grained	93	2.660	--	16,820	9,910
"	13	Coarse Grained, Vertical Fracture	122	2.648	55.3	19,700	11,540
"	15	Coarse Grained, Horizontal Fractures	142	2.648	51.5	20,700	12,320
"	17	Intact, Coarse Grained	159	2.667	--	22,850	11,990
"	19	Intact, Coarse Grained	178	2.665	56.8	20,210	11,980
"	21	Intact, Coarse Grained	198	2.677	56.7	22,880	11,750
	Average of Weathered Specimens (2)			2.652	43.0	13,940	8,700
	Average of Unweathered Specimens (8)			2.663	53.7	20,850	11,790

4. The Schmidt hammer test was not conducted on several specimens due to possibility of breakage. The weathering detrimentally affected the physical properties, but not to the point of incompetency. Weathered and unweathered rock were also the primary groupings for hole MA-CR-4 which was apparently located in the same general rock body.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 9, 13, and 21. Stress-strain curves are given in plates 1, 2, and 3. Specimens 13 and 21 were cycled at 10,000 psi. Specimen 9 was cycled at 5000 psi. Results are given below.

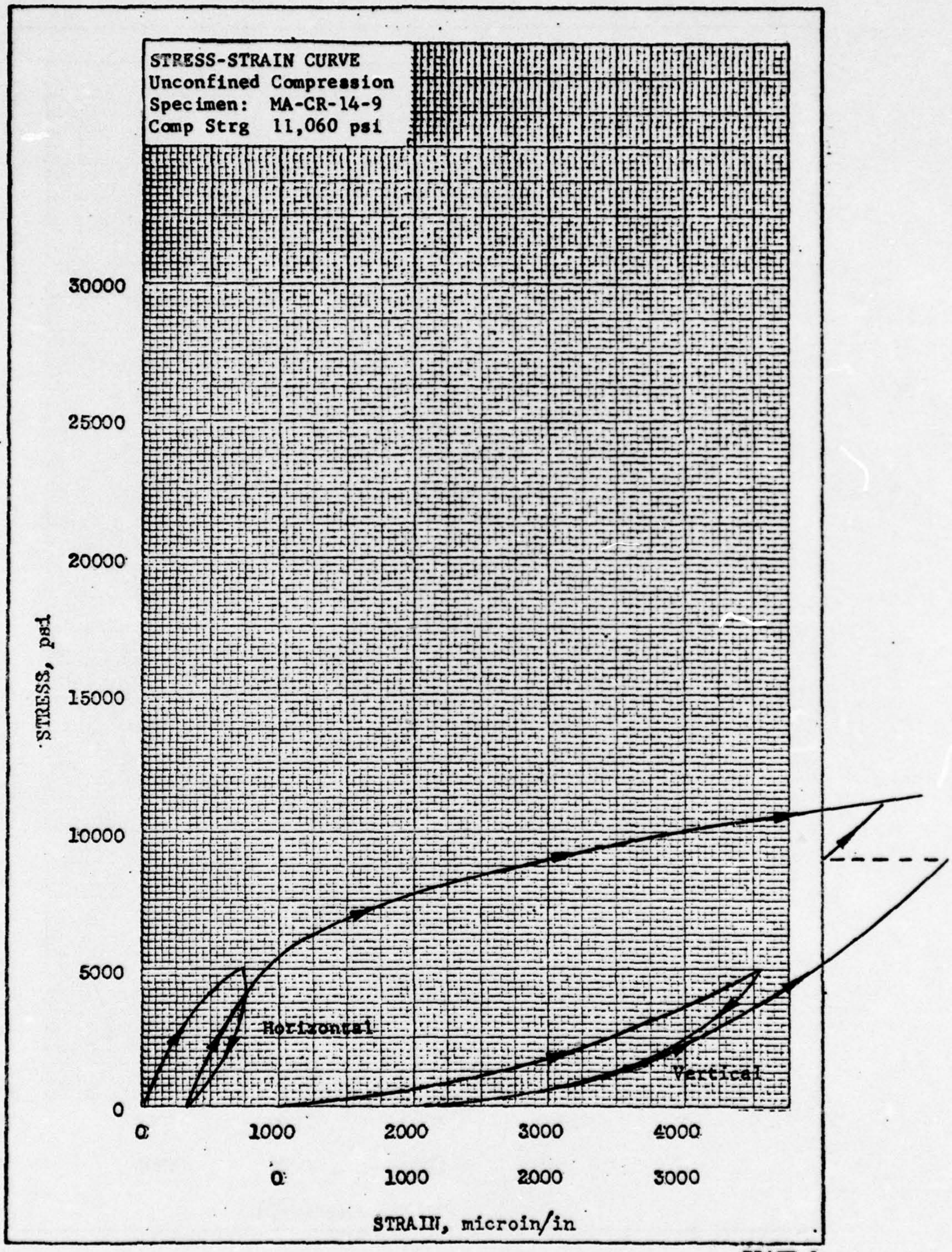
Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
2	3.8	2.2	1.6	6640	0.21
5	4.9	2.8	2.0	7500	0.21
7	4.2	2.4	1.7	6950	0.20
9	2.0	0.7	1.0	5170	0.04
10	3.2	1.8	1.3	6080	0.20
13	4.2	2.4	1.8	7020	0.21
15	5.0	2.6	2.1	7680	0.18
17	4.7	2.6	2.0	7370	0.20
19	4.9	2.3	2.1	7660	0.15
21	4.8	2.2	2.1	7600	0.14
		Static Tests			
9	3.4	1.8	1.4	--	0.19
13	7.6	6.5	2.9	--	0.31
21	7.8	3.1	3.6	--	0.09

The material subjected to static tests was rather brittle, exhibiting some hysteresis and residual strain. Dynamic moduli exhibited by this material were low, possibly due to the porphyritic texture of the rock.

Conclusions

6. The material received for testing from hole MA-CR-14 was identified by the field log received with the core as black and white granite porphyry. Specimen Nos. 4, 5, 12, 13, 15, and 18 contained fractures; Nos. 9 and 10 appeared to be somewhat weathered. The core tested from hole MA-CR-14 was very similar to that tested from hole MA-CR-4, both in appearance and physical test results. The weathered material from hole 14 was somewhat weaker than the unweathered core, but was still relatively competent. The unweathered core was quite uniform and competent, despite some fracturing in several pieces. A comparison of test results from holes MA-CR-14 and MA-CR-4 is given below:

Property	Weathered Material		Unweathered Material	
	MA-CR-14	MA-CR-4	MA-CR-14	MA-CR-4
Specific Gravity	2.652	2.627	2.663	2.644
Schmidt Number	43.0	50.1	53.7	53.5
Compressive Strength, psi	13,940	12,280	20,850	23,710
Compressional Wave Velocity, fps	8,700	11,240	11,790	14,250
Static Young's Modulus, psi x 10^6	3.4	--	7.7	7.4
Dynamic Young's Modulus, psi x 10^6	2.6	4.0	4.6	5.6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Unconfined Compression
Specimen: MA-CR-14-9
Comp Strg 11,060 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1

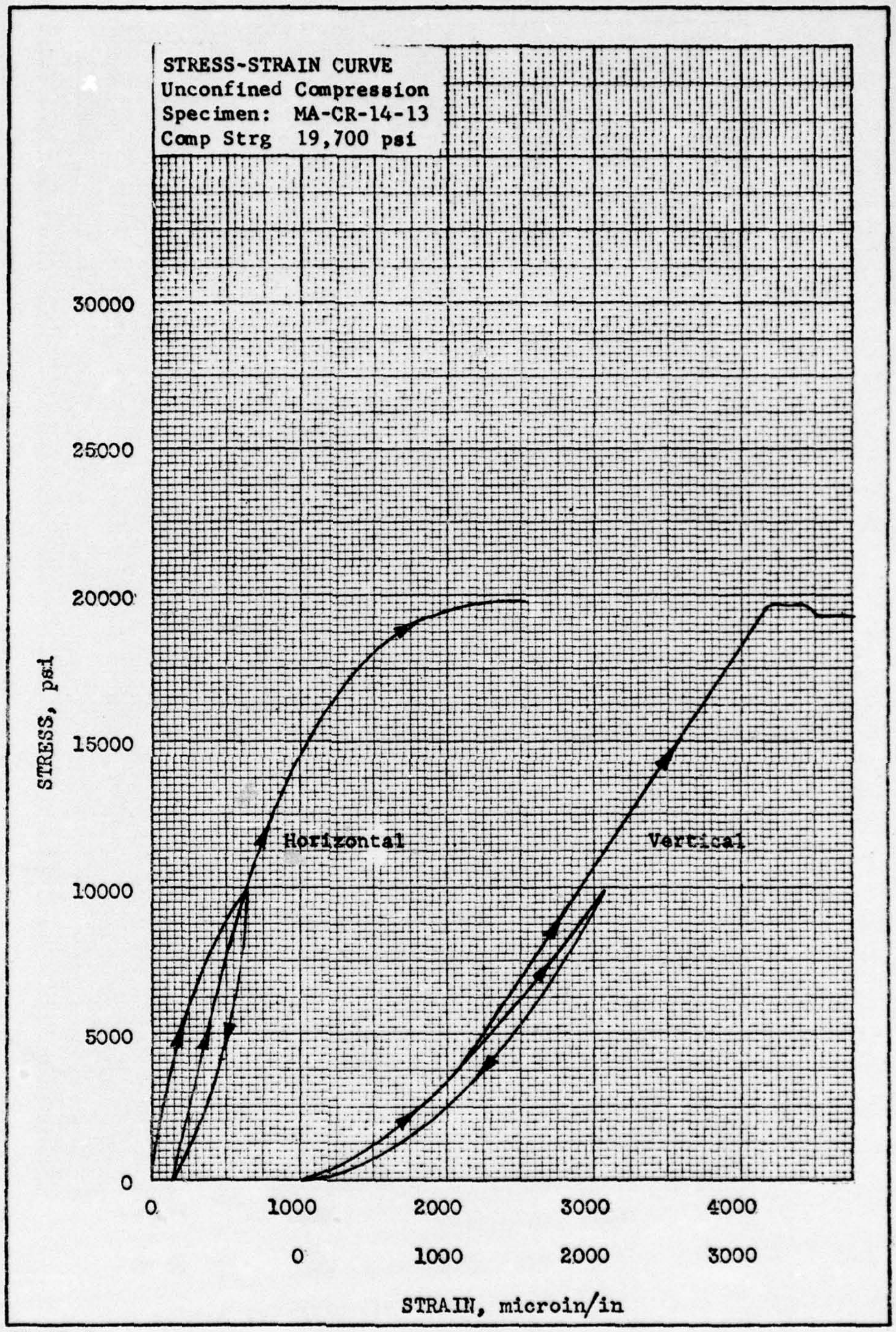
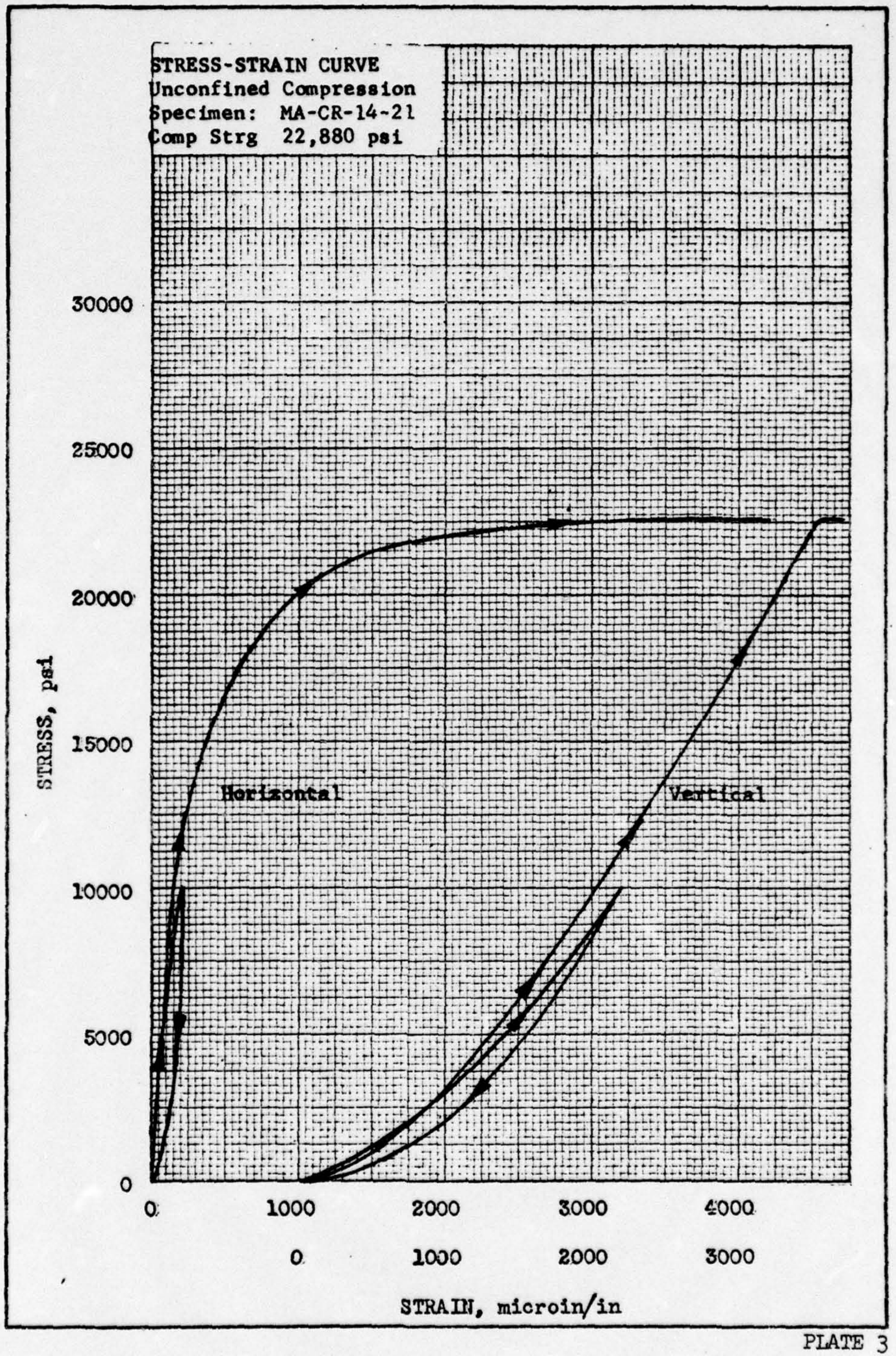

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-14-13
Comp Strg 19,700 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2


STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-14-21
Comp Strg 22,880 psi
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20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 3

APPENDIX E

DATA REPORT

Hole MA-CR-18

5 December 1969

Hole Location: Washington County, Maine

Longitude: 67° 33' 47" West

Latitude: 44° 48' 22" North

Core

1. The following core was received on 24 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	7
2	19
3	26
4	32
5	39
6	43
7	47
8	54
9	61
10	64
11	65
12	73
13	79
14	82
15	98
16	100
17	110
18	120
19	129
20	139
21	150
22	160
23	169
24	177
25	181
26	190
27	198

Description

2. The samples received were quite variable in appearance. According to the field log received with the core, the rock was identified as basalt, gabbro, granodiorite, and quartz. Specimen Nos. 2, 4, 5, 6, 7, 8, 9, 10, 12,

13, 14, 15, 16, 17, 20, 25, and 27 contained fractures; Nos. 11, 13, and 25 contained contact zones. Many of the fractures were tightly closed.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.*	Ultimate Comp Strg, psi	Comp Wave Vel, fps
3	Intact Gabbro	26	2.886	--	25,240	15,550
6	Fractured ~~Gabbro~~ Basalt	43	2.997	--	19,240	18,210
8	Fractured ~~Granodiorite~~ Tonalite	54	2.682	--	29,560	14,050
9	Highly Fractured ~~Gabbro~~ Basalt	61	2.983	--	6,360	15,190
11	Basalt-~~Granodiorite~~ Tonalite Contact	65	2.632	53.8	24,090	15,490
13	Fractured ~~Granodiorite~~ Tonalite Gabbro Contact	79	2.794	52.5	10,680	18,990
16	Highly Fractured Gabbro	100	2.891	--	6,000	16,420

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

(Continued)

(Continued)

Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.*	Ultimate Comp Strg. psi	Comp Wave Vel. fps
18	Intact Gabbro	120	2.943	--	43,940	17,030
20	Fractured Gabbro	139	3.002	53.9	34,850	17,780
22	Intact Gabbro	160	3.010	--	47,420	18,570
24	Intact Gabbro	177	2.918	51.2	20,150	18,870
25	Quartz-Gabbro Contact	181	2.754	54.8	18,030	18,120
27	Fractured Gabbro	198	3.066	53.5	27,880	21,060
Highly Fractured Specimens (2)			2.937	--	6,180	15,800
Specimens Containing Contact Zones (3)			2.727	53.7	17,600	17,530
Slightly Fractured and Intact Specimens (8)			2.938	52.9	31,040	17,640

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Due to the rather wide variety of material tested from this hole, coupled with the wide variation in nature and degree of fracturing present, physical test results showed considerable variation; however, only the highly fractured gabbro was found to be incompetent rock. The fact that the compressional wave velocities for the slightly fractured to intact core were nearly equal to those exhibited by the contact zone specimens would seem to indicate that the contacts were very tightly closed.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 6, 11, and 27. Stress-strain curves are given in plates 1, 2, and 3. The three specimens were cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	7.6	5.4	3.0	8,770	0.27
6	8.9	9.0	3.3	9,060	0.34
8	6.0	3.9	2.4	8,180	0.24
9	6.4	6.0	2.4	7,770	0.32
11	7.0	4.8	2.8	8,830	0.26
13	9.9	8.6	3.8	10,000	0.31
16	7.6	6.6	2.9	8,660	0.31
18	8.6	7.1	3.3	9,160	0.30
20	9.7	7.8	3.8	9,650	0.29
22	9.7	9.1	3.7	9,520	0.32
24	9.6	9.2	3.6	9,610	0.33
25	8.6	7.8	3.3	9,370	0.32
27	12.5	12.0	4.7	10,680	0.33
		Static Tests			
6	11.4	5.3	5.0	--	0.14
11	9.1	4.5	3.9	--	0.17
27	12.5	6.8	5.2	--	0.19

The material subjected to static tests was quite brittle, exhibiting slight hysteresis and residual strain.

Conclusions

6. The core received for testing from hole MA CR-18 was quite variable, identified by the field log received with the core as basalt, gabbro, granodiorite, and quartz. Specimen Nos. 2, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 20, 25, and 27 contained fractures, many of which were tightly closed; Nos. 11, 13, and 25 contained contact zones. The highly fractured material from this hole was very incompetent. The slightly fractured to intact material was generally quite competent, but test results showed considerable variation. Compressive strengths for this group ranged from 19,000 to 47,000 psi. The specimens containing contact zones, while not as competent as the slightly fractured to intact core, were still relatively competent. The relatively high compressional wave velocities exhibited by the specimens containing contact zones would seem to indicate that the contacts were tightly closed.

Property	Highly Fractured Material	Slightly Fractured to Intact Material	Zones of Contact
Specific Gravity	2.937	2.938	2.727
Schmidt Number	--	52.9	53.7
Compressive Strength, psi	6,180	31,040	17,600
Compressional Wave Velocity, fps	15,800	17,640	17,530
Static Young's Modulus, psi x 10^6	--	12.0	9.1

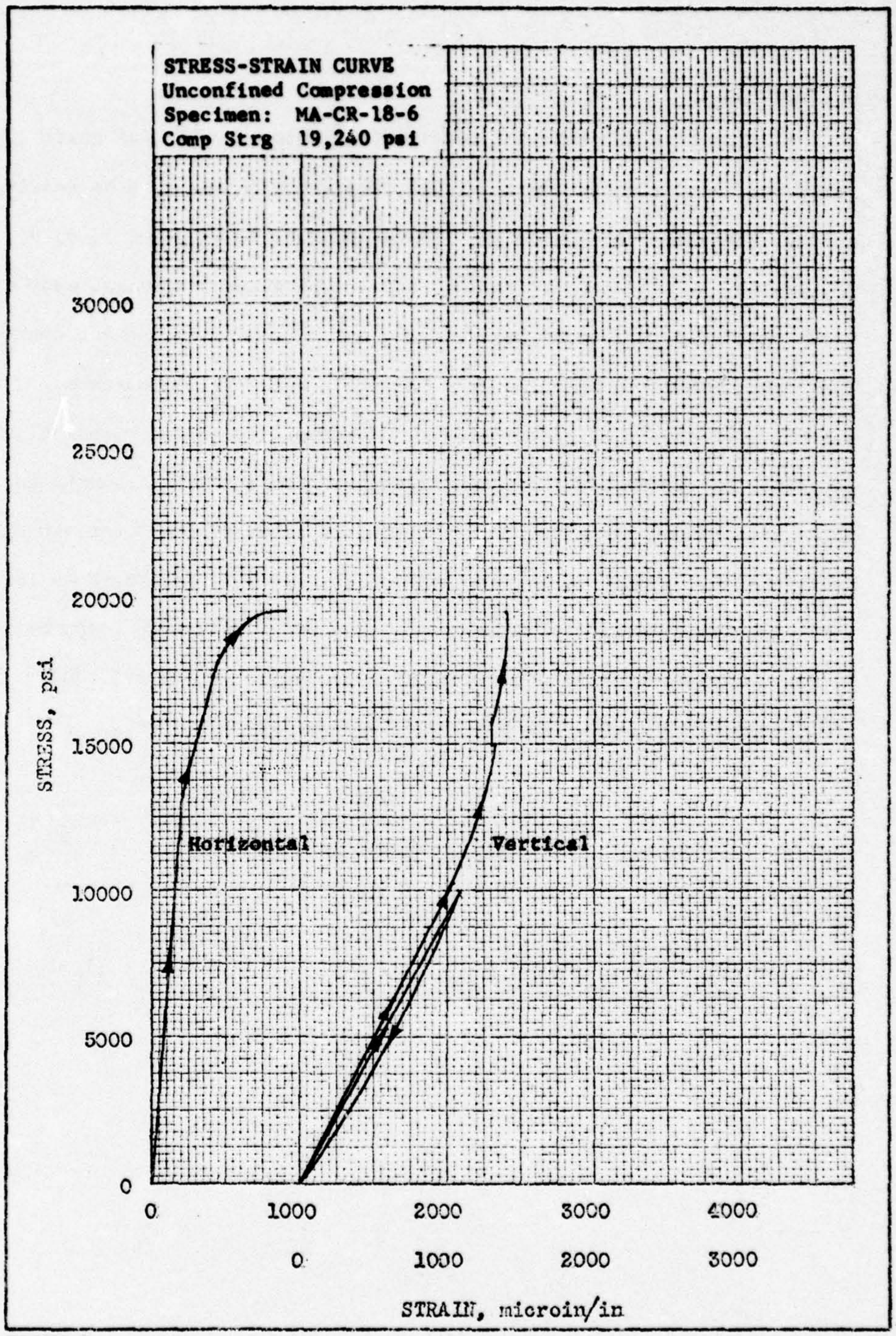

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-18-6
Comp Strg 19,240 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1

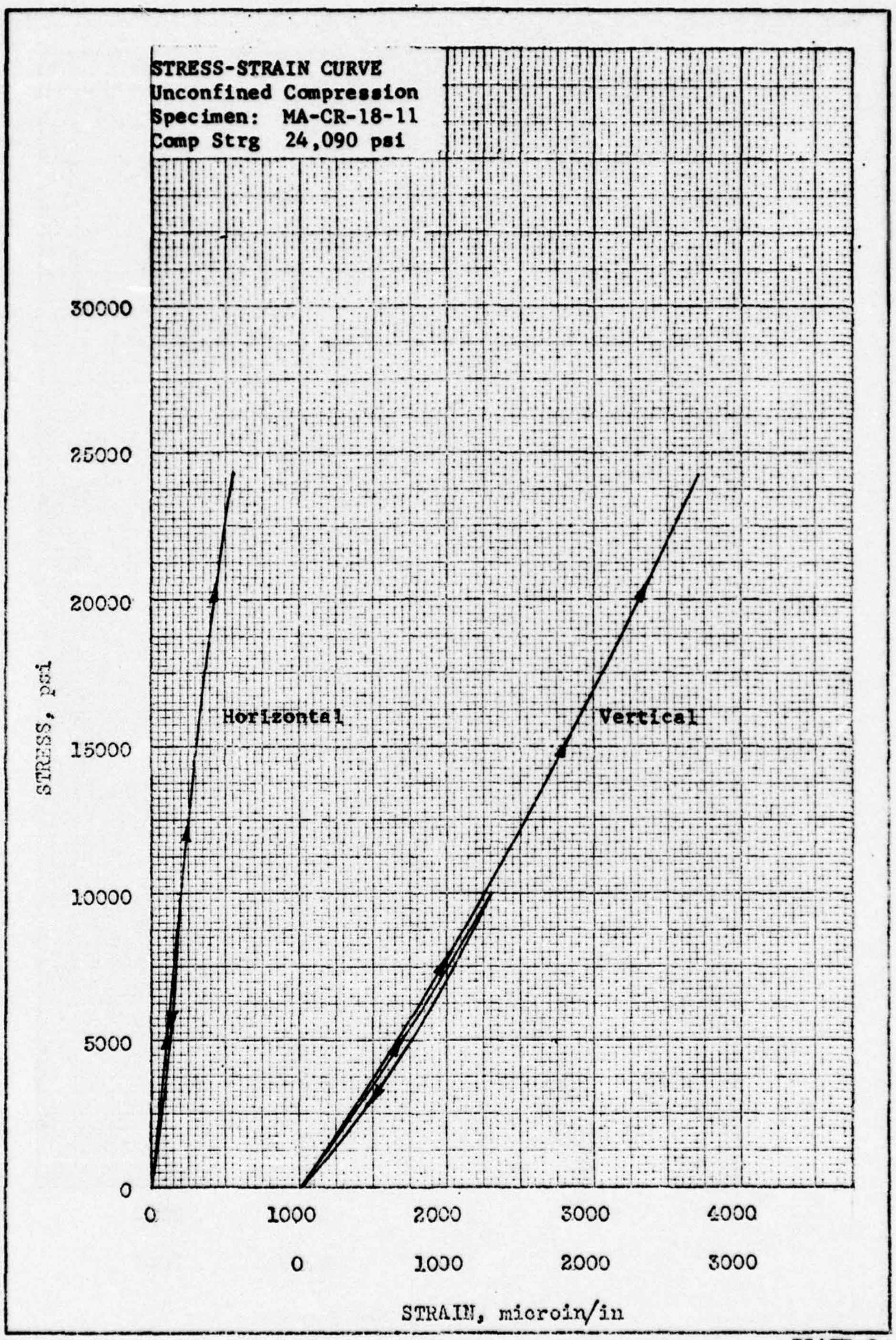

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-18-11
Comp Strg 24,090 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

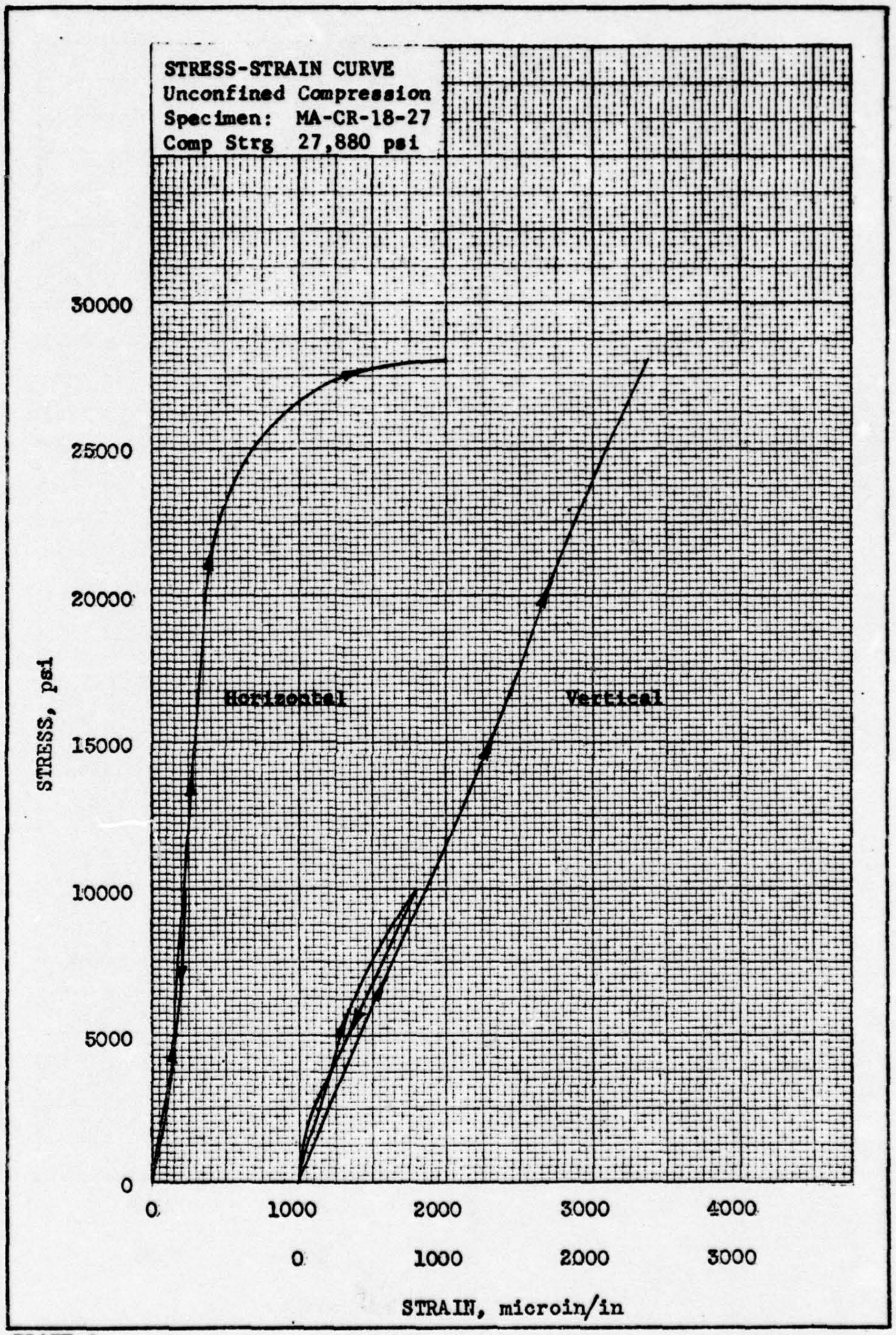

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-18-27
Comp Strg 27,880 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 3

APPENDIX F

DATA REPORT

Hole MA-CR-20

9 December 1969

Hole Location: Washington County, Maine

Longitude: 67^{o} 34' West

Latitude: 44^{o} 48' North

Core

1. The following core was received on 25 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	6
2	14
3	23
4	33
5	42
6	50
7	62
8	72
9	82
10	91
11	101
12	113
13	119
14	124
15	131
16	144
17	156
18	163
19	172
20	188
21	196

Description

2. The samples received were rather uniform in appearance. According to the field log received with the core, the rock was identified as pink, medium-grained granite. Specimen Nos. 1, 4, 7, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21 contained fractures, some of which were filled with quartz; Nos. 1, 7, 10, 12, 15, 16, and 20 were weathered to various degrees.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.*	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Medium-grained granite	3	Intact	23	2.632	53.2	30,680	17,620
"	5	Intact	42	2.636	56.9	27,880	17,800
"	7	Intact, Weathered	62	2.618	--	25,620	18,410
"	9	Intact	82	2.588	55.2	19,760	18,160
"	11	Intact	101	2.508	57.2	29,880	19,480
"	13	Fractured	119	2.607	--	17,060	18,050
"	15	Fractured, Weathered	131	2.579	50.9	5,760	17,240
"	16	Fractured, Weathered	144	2.500	41.2	6,300	14,260
"	17	Quartz-Filled Fractures	156	2.631	50.0	19,240	17,780
"	18	Quartz-Filled Fractures	163	2.619	45.5	11,030	18,070
"	19	Quartz-Filled Fractures	172	2.619	55.7	21,850	19,100
"	20**	Fractured, Weathered	188	2.513	--	--	12,220
"	21	Open Fracture Critically Oriented	196	2.585	52.5	2,120	17,340
Specimens Both Fractured and Weathered or Containing Open Fractures (3)				2.555	48.2	4,730	16,280
Specimens Containing Quartz-Filled Fractures (3)				2.623	50.4	17,370	18,320
Remainder of Specimens (6)				2.598	55.6	25,150	18,250

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

** Specimen broke during preparation for testing.

Moduli of deformation

4. **Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from** theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 3 and 17. Stress-strain curves are given in plates 1 and 2. Both specimens were cycled at 10,000 psi. Results are given below.

Specimen	Modulus, psi x 10^6			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
			Dynamic Tests		
3	8.0	6.9	3.1	9,300	0.31
5	8.2	7.1	3.1	9,390	0.31
7	9.0	7.4	3.4	9,890	0.30
9	8.6	7.1	3.3	9,770	0.30
11	9.1	8.2	3.4	10,110	0.32
13	6.1	8.5	2.2	7,940	0.38
15	6.1	7.3	2.2	8,040	0.36
16	5.3	4.1	2.1	7,850	0.28
17	9.6	6.0	3.9	10,490	0.23
18	8.5	7.1	3.3	9,640	0.30
19	10.3	7.4	4.1	10,760	0.27
20	4.6	2.5	1.9	7,490	0.20
21	8.1	6.2	3.2	9,530	0.28
			Static Tests		
3	9.3	5.4	3.8	--	0.21
17	10.9	4.0	5.2	--	0.05

The material subjected to static tests was very brittle, exhibiting negligible hysteresis and residual strain.

Conclusions

5. The material received for testing from hole MA-CR-20 was rather uniform in appearance, identified by the field log received with the core as a pink, medium-grained granite. Many specimens contained fractures, some of which were filled with quartz. Several specimens were weathered. Except for the specimen containing an open, critically oriented fracture and those which were both fractured and weathered, the material from this hole was relatively competent. The core containing either open or weathered fractures was, however, very incompetent. Physical test results for all specimens tested were quite variable, possibly due to the wide variation in nature and degree of fracturing and weathering.

Property	Specimens Both Fractured and Weathered or Containing Open Fractures	Specimens Containing Quartz-Filled Fractures	Remainder of Specimens
Specific Gravity	2.555	2.623	2.598
Schmidt Number	48.2	50.4	55.6
Compressive Strength, psi	4,730	17,370	25,150
Compressional Wave Velocity, fps	16,280	18,320	18,250
Static Young's Modulus, psi x 10^6	--	10.9	9.3

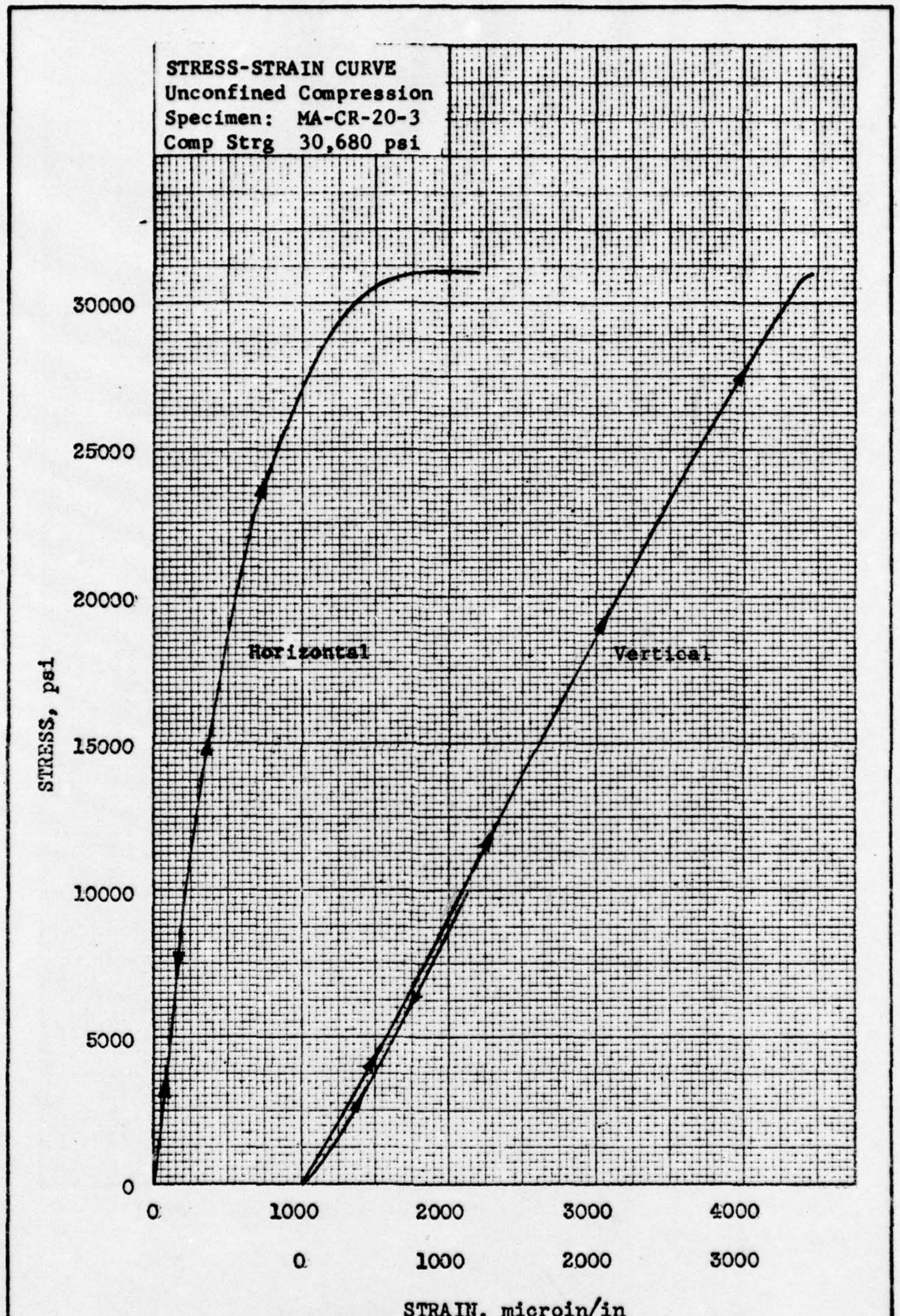

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-20-3
Comp Strg 30,680 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1

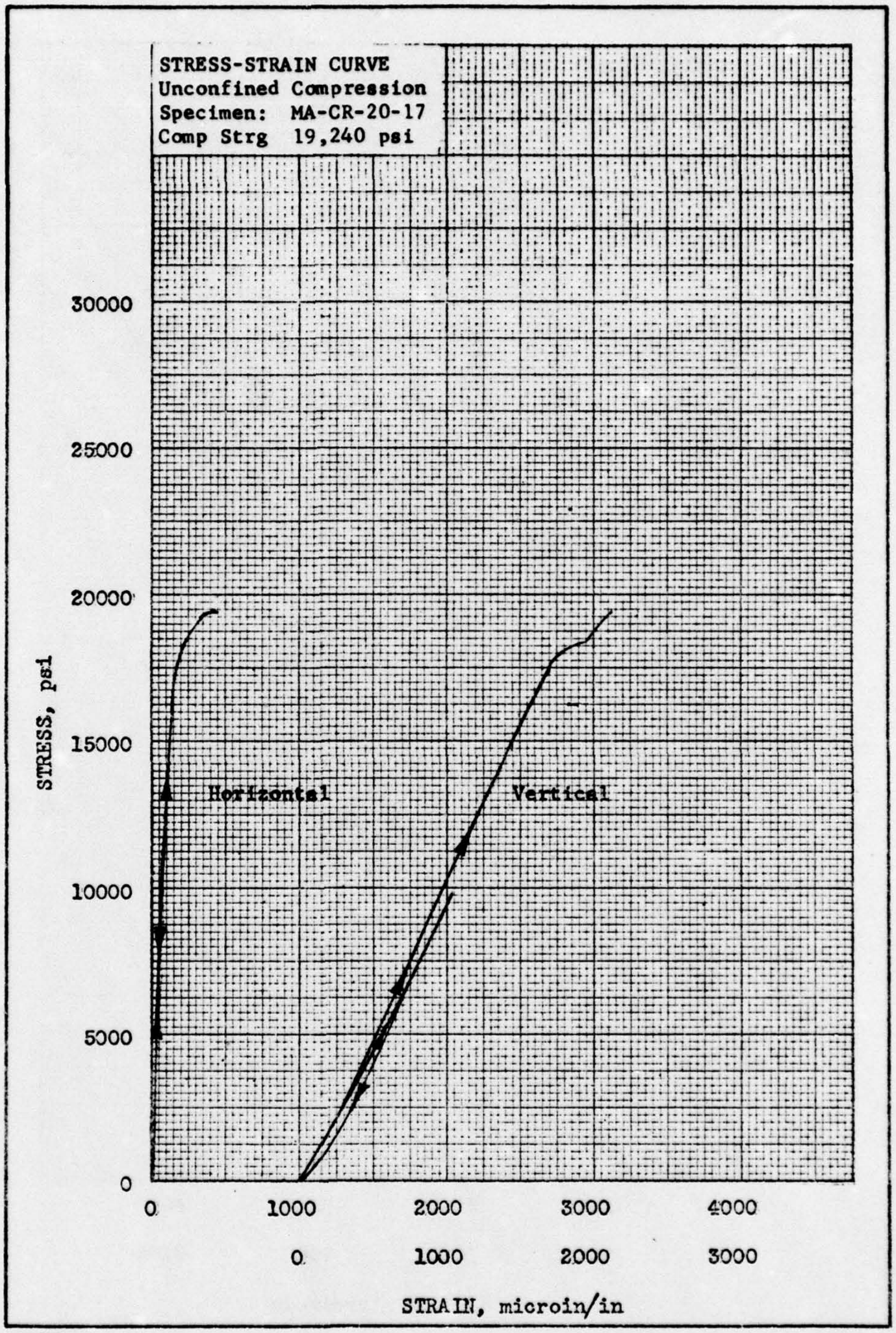

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-20-17
Comp Strg 19,240 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

APPENDIX G

DATA REPORT

Hole MA-CR-29

3 December 1969

Hole Location: Washington County, Maine

Longitude: 67° 09' 37.2" West

Latitude: 45° 04' 31.8" North

Core

1. The following core was received on 20 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	9
2	19
3	27
4	35
5	46
6	55
7	67
8	76
9	85
10	91
11	96
12	104
13	117
14	125
15	130
16	138
17	148
18	157
19	164
20	173
21	182
22	189
23	194

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as salmon red, fine-grained metavolcanics. All specimens except Nos. 11 and 16 contained fractures, most of which were tightly closed; Nos. 11, 13, 16, and 22 contained vesicles.

Quality and uniformity tests

3. To determine the variations in physical properties within a hole, specific gravity (sp gr), Schmidt number, ultimate compressive strength (comp strg), and compressional wave velocity (comp wave vel) were determined on specimens prepared from representative samples of the received rock. The results of these tests are given below:

	Sample No.	Description	Core Depth ft	Sp Gr	Schmidt No.	Ultimate Comp Strg, psi	Comp Wave Vel, fps
Fine-grained Rhyolite	3	Highly Fractured	27	2.649	--	11,700	18,000
"	4	Highly Fractured	35	2.648	--	14,060	18,160
"	7	Critically Fractured	67	2.647	53.8	12,420	18,860
"	9	Several Near Vertical Fractures	85	2.654	52.7	34,550	18,560
"	11	No Fractures, Many Large Vesicles	96	2.617	54.0	34,550	17,200
"	13	Highly Fractured, Few Vesicles	117	2.637	48.3	7,580	18,040
"	15	Several Critically Oriented Fractures	130	2.645	48.5	6,090	17,260
"	16	No Fractures, Few Vesicles	138	2.672	51.7	37,880	18,220
"	18	Single Fracture	157	2.685	--	29,060	18,700
"	19	Horizontal and Vertical Fractures	164	2.684	--	26,700	18,680
"	22	Horizontal and Vertical Fractures, Few Vesicles	189	2.665	56.8	26,640	17,470
	Average of Critically and Highly Fractured Specimens (5)			2.645	50.2	10,370	18,060
	Average of Remainder of Specimens (6)			2.662	53.8	31,560	18,140

4. The Schmidt hammer test was not conducted on several specimens due to possibility of breakage. The material tested from this hole yielded ultimate compressive strengths which correlated well with the nature and degree of fracturing present, i.e., the highly fractured specimens and those containing critically oriented fractures were appreciably weaker than the intact specimens or those containing horizontal and/or vertical fractures.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 3, 11, and 16. Stress-strain curves are given in plates 1, 2, and 3. All three specimens were cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	8.7	7.1	3.4	9,680	0.30
4	8.7	7.3	3.3	9,680	0.30
7	9.4	7.9	3.6	10,050	0.30
9	9.3	7.6	3.6	10,000	0.30
11	7.8	6.4	3.0	9,220	0.30
13	8.3	7.4	3.2	9,420	0.31
15	8.2	6.3	3.2	9,490	0.28
16	9.0	7.3	3.5	9,800	0.30
18	9.6	7.7	3.7	10,110	0.29
19	9.5	7.7	3.7	10,100	0.29
22	7.6	7.2	2.9	8,920	0.32

(Continued)

(Continued)

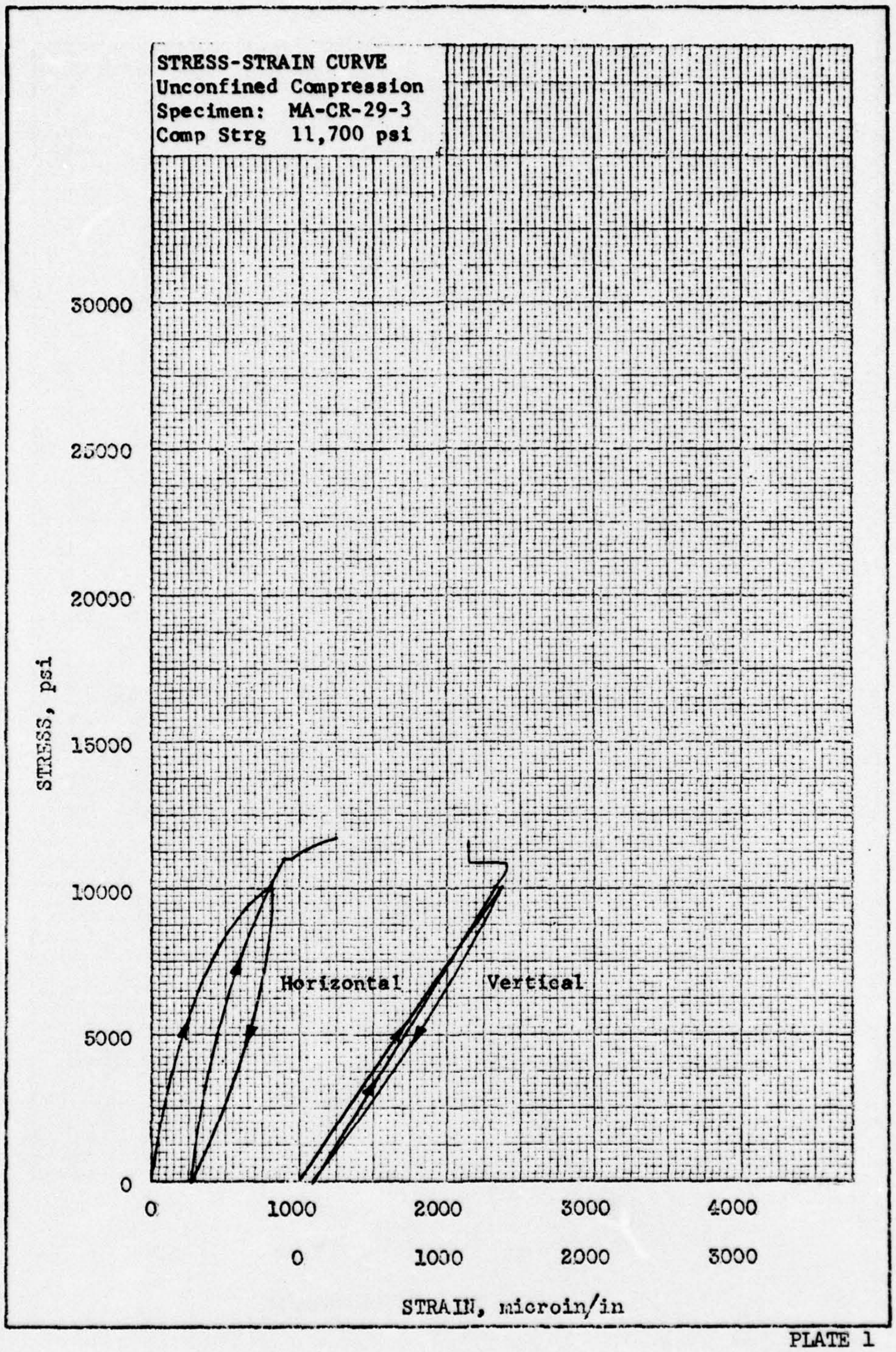
Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Static Tests			
3	7.3	6.4	2.8	--	0.31
11	8.0	4.0	3.4	--	0.16
16	10.0	8.8	3.8	--	0.31

The material tested herein was quite brittle, and except for the highly fractured specimen, exhibited little hysteresis.

Conclusions

6. The core received for testing from hole MA-CR-29 was relatively uniform in appearance, identified by the field log received with the core as salmon red, fine-grained metavolcanics. All specimens except Nos. 11 and 16 contained fractures, most of which were tightly closed; Nos. 11, 13, 16, and 22 contained vesicles. The highly fractured specimens and those containing critically oriented fractures exhibited much lower compressive strengths than did the intact specimens or those containing horizontal and/or vertical fractures. The vesicles present in four specimens had no apparent effect on compressive strength; nature and degree of fracturing appeared to be the governing characteristic.

Property	Critically and/or Highly Fractured Specimens	Remainder of Specimens
Specific Gravity	2.645	2.662
Schmidt Number	50.2	53.8
Compressive Strength, psi	10,370	31,560
Compressional Wave Velocity, fps	18,060	18,140
Static Young's Modulus, psi x 10^6	7.3	9.0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Unconfined Compression
Specimen: MA-CR-29-3
Comp Strg 11,700 psi
STRESS, psi
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25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 1

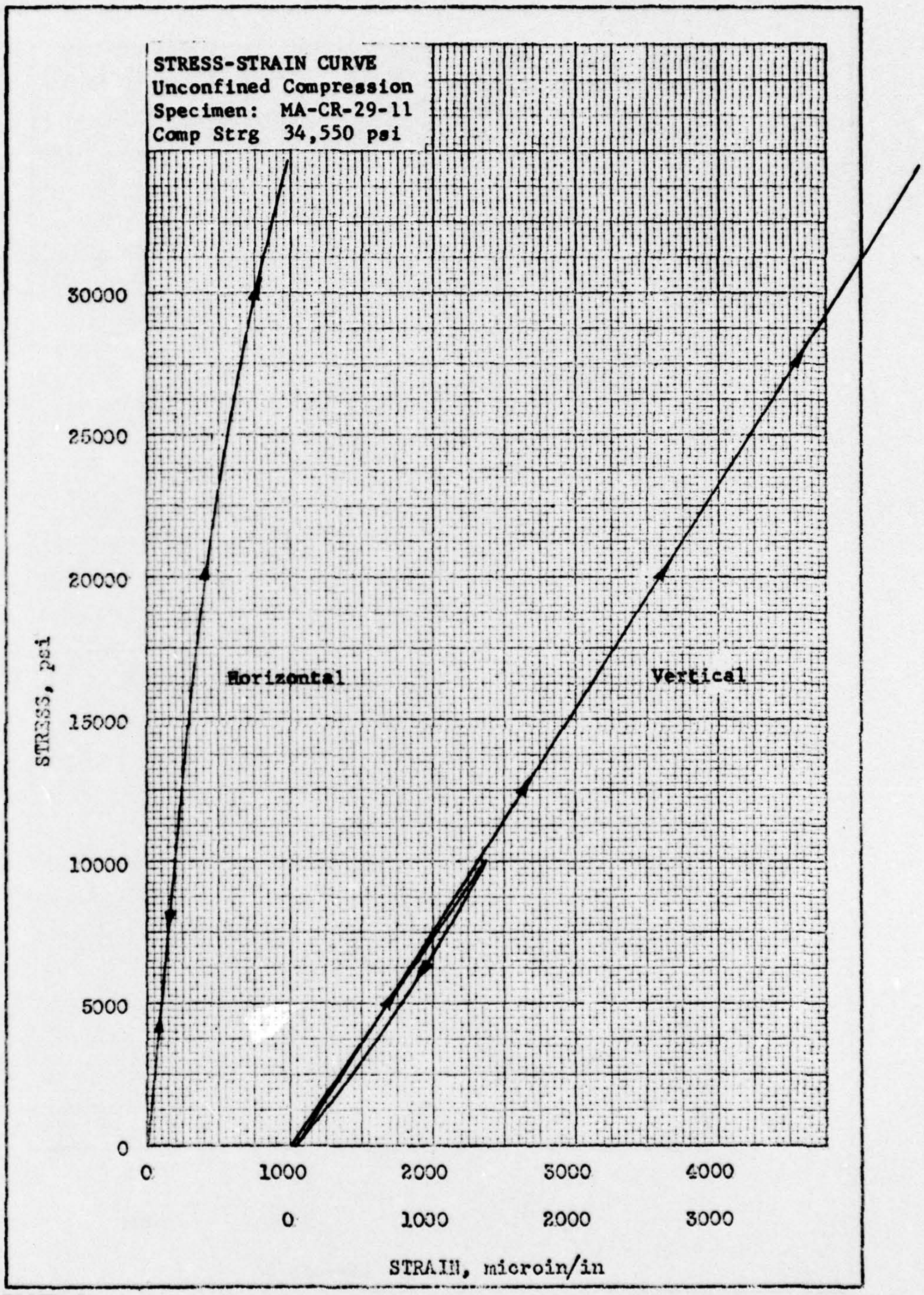
STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-29-11
Comp Strg 34,550 psi
Horizontal
Vertical
STRESS, psi
30000
25000
20000
15000
10000
5000
0
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 2

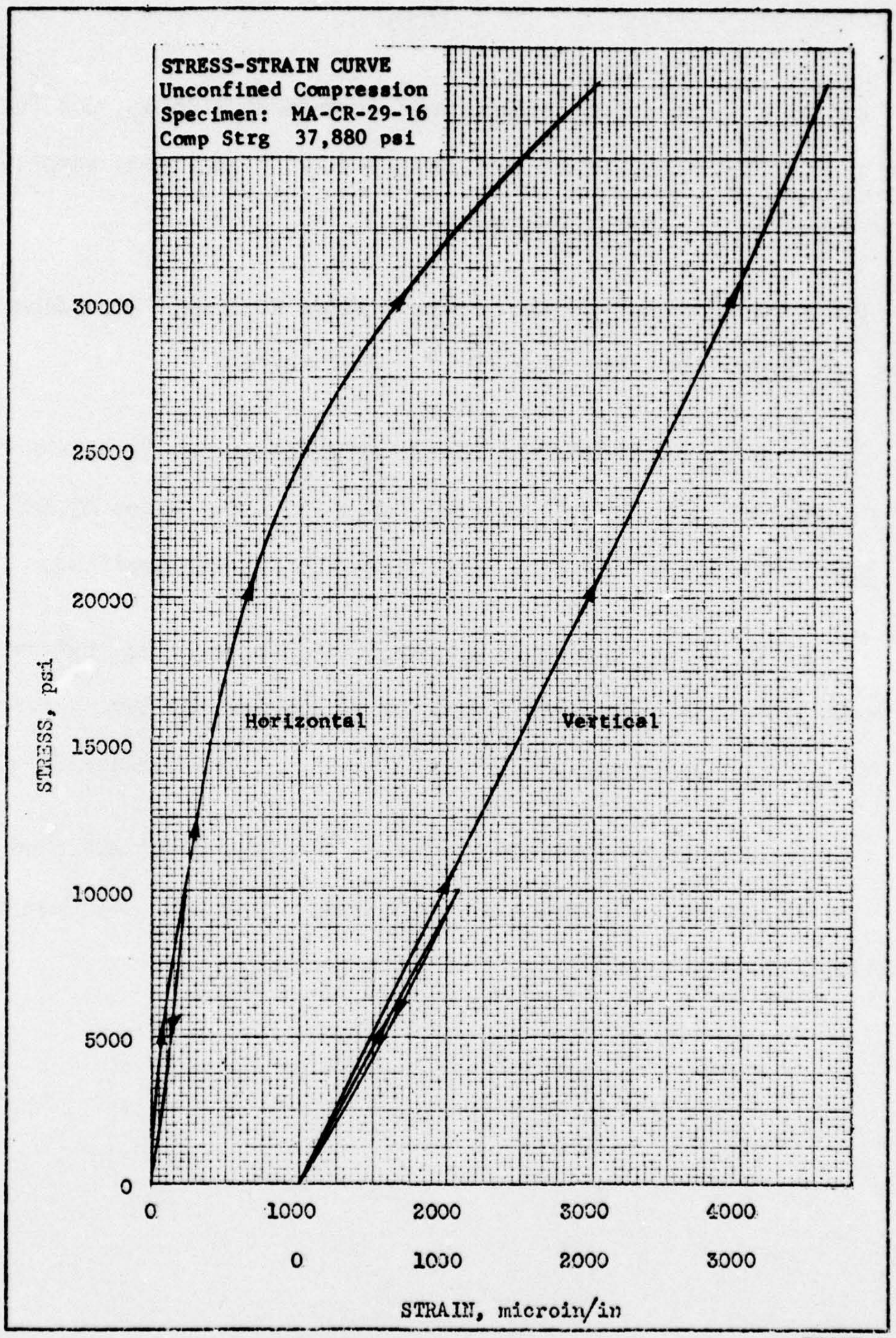
STRESS-STRAIN CURVE
Unconfined Compression
Specimen: MA-CR-29-16
Comp Strg 37,880 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE 3

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13. ABSTRACT

Laboratory tests were conducted on representative rock core specimens received from six core holes located in Hancock and Washington Counties in Maine. The results of these tests were used to gage the quality and uniformity of the rock to depths of 200 feet below ground surface. The core was petrographically identified as predominantly granite with lesser amounts of rhyolite, basalt, and gabbro. Schmidt hardness, specific gravities, compressional wave velocities, and ultimate uniaxial compressive strengths varied somewhat throughout the area, depending primarily on rock type, texture, and nature and degree of fracturing present, if any. Evaluation of the materials from the Machias study area on a hole-to-hole basis indicates that the porphyritic granite is quite uniform and rather competent, offering good possibilities as a competent hard rock medium. The uniformly medium-grained granite was somewhat more variable, with one specimen from Hole MA-CR-13 (at a depth of 39 feet) and several specimens from Hole MA-CR-20 yielding physical test results typical of incompetent rock. The intact medium-grained granite should offer relatively good possibilities as a competent hard rock medium; the highly fractured, medium-grained granite and that containing weathered fracture surfaces were, however, generally incompetent and therefore unsatisfactory. The rhyolite and the basalt and gabbro must also be considered unsatisfactory, as specimens removed at depths greater than 100 feet from each of these holes exhibited physical characteristics typical of incompetent rock. The above evaluations were based on rather limited data. Therefore, more extensive investigation will be required in order to accurately assess the areas under consideration.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Machias Study Area, Maine						
Rock cores						
Rock properties						
Rock tests						